Aalto University
School of Engineering
Degree Programme in Structural Engineering and Building Technology

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Assessing alternatives for using building information models to manage initial information in building renovation projects

Master's Thesis
Espoo, April 22, 2014

Supervisor: Professor Vishal Singh
Advisor: Auli Karjalainen M.Sc. (Architecture)

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ABSTRACT OF MASTER'S THESIS

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This thesis studies the potential use of building information models for managing the useful minimum initial information in renovation projects. A building information model (BIM) is a digital representation of the physical and functional properties of a building. This research seeks answers to the questions (1) what information is needed in the early phases of a renovation project? (2) how can this information be managed with BIMs? (3) how is value added to the facility owner through the use of BIM in these stages? (4) when and how should inventory models be created? and (5) how should building information models be maintained?

The research has been done through case studies of renovation projects at Senate Properties. In total, 21 face-to-face interviews were conducted. Among the 21 interviewees, 9 came from three different renovation case projects, 5 interviewees were associated with the need evaluation phase, and the remaining 7 interviewees were chosen based on their recognized expertise in BIM and information management.

The conclusion of the thesis is that the model requirements varies across cases and project phases, such that the need for the model should be evaluated on a case-by-case and phase-by-phase basis. In general, inventory models should be created as early as possible when the need for a model is established. Models should be created for the needs in the current phase and for the current designer, and not for future phases. For managing the structural properties and dimensions of the building, a building frame model should be created by the project structural engineer in the conceptual design phase. For managing and checking the initial information, a space model including only the building spaces could be created by the project architect in the need evaluation phase.

Keywords:	BIM, inventory model, information management, building renovation, model maintenance, initial information
Language:	English

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Rakenne- ja rakennustuotantotekniikan koulutusohjelma

DIPLOMITYÖN TIIVISTELMÄ

Tekijä:	David Helander		
Työn nimi: Vaihtoehtojen arviointi tietomallien hyödyntämiseen korjausprojektin lähtötietojen hallintaan			
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Ohjaaja:	Arkkitehti Auli Karjalainen		

Tässä diplomityössä tutkitaan tietomallien hyödyntämistä korjausprojektin käyttökelpoisten vähimmäislähtötietojen hallintaan. Rakennuksen tietomalli on digitaalinen esitys rakennuksen fyysisistä ja toiminnallisista ominaisuuksista. Tutkielmassa etsitään vastausta seuraaviin kysymyksiin: (1) Mitkä lähtötietotarpeet ovat olemassa korjausprojektin alkuvaiheissa? (2) Miten näitä tietoja voidaan hallita tietomalleilla? (3) Miten nämä mallit lisäävät arvoa kiinteistönomistajalle tutkituissa vaiheissa? (4) Milloin ja miten inventointimalli kannattaisi tehdä? (5) Miten rakennusten tietomalleja pitäisi ylläpitää?

Diplomityössä on tutkittu lähtötietotarpeet kolmessa korjaushankkeessa Senaatti-kiinteistössä. Aineisto sisältää yhteensä 21 haastattelua, jotka tehtiin kasvotusten. Näiden 21 haastateltavan joukosta 9 henkilöä on korjaushankkeista ja 5 henkilöä tarveselvitysvaiheesta, ja 7 haastateltavaa valittiin heidän tietomalli- ja tiedonhallinta-asiantuntemuksensa perusteella.

Diplomityön johtopäätöksenä on, että tietomallien tarpeellisuus vaihtelee hankkeiden ja vaiheiden välillä, minkä vuoksi mallin tarpeellisuutta täytyy arvioida vaihekohtaisesti ja hankekohtaisesti. Yleensä inventointimalli pitäisi tehdä mahdollisimman aikaisin, kun tarve mallille on todettu. Malli kannattaisi tehdä nykyistä vaihetta ja suunnittelijaa varten, eikä tulevia vaiheita varten. Malli rakennuksen rungosta kannattaisi tehdä rakenteellisten ominaisuuksien ja mittojen hallintaan. Projektin rakennesuunnittelijan pitäisi tehdä tämä malli hankesuunnitteluvaiheessa. Lähtötietojen organisoimiseen ja tarkistamiseen voidaan tehdä tilamalli, joka sisältää vain rakennuksen tiloja. Tilamalli kannattaisi tehdä arkkitehdin toimesta tarveselvitysvaiheessa.

Asiasanat:	Tietomalli, inventointimalli, tiedonhallinta, korjausrakentaminen, mallin ylläpito, lähtötietoja
Kieli:	Englanti

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SAMMANDRAG AV DIPLOMARBETET

Utfört av:	David Helander		
Arbetets namn: Utvärdering av alternativ för användningen av byggnadsinformationsmodeller för att hantera information i början av renoveringsprojekt			
Datum:	Den 22 april 2014	**Sidantal:**	xi + 93
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Övervakare:	Professor Vishal Singh		
Handledare:	Arkitekt Auli Karjalainen		

Detta diplomarbete har undersökt hur byggnadsinformationsmodeller kan användas för att hantera information i början av byggnadsrenoveringsprojekt. En byggnadsinformationsmodell (BIM) är en digital framställning av en byggnads fysiska och funktionella egenskaper. De fem forskningsfrågor som undersökts i arbetet är: (1) Vilken information behövs i början av renoveringsprojekt? (2) Hur kan denna information hanteras med hjälp av BIM? (3) Hur tillför användningen av BIM värde för fastighetsägaren i de undersökta faserna? (4) När och hur skall inventeringsmodeller göras? och (5) Hur ska byggnadsinformationsmodeller underhållas?

I diplomarbetet undersöktes informationsbehovet i början av tre renoveringsprojekt utförda av Senatfastigheter. Totalt utfördes 21 intervjuer ansikte mot ansikte. Av de 21 intervjuade var 9 personer från de tre renoveringsprojekten, 5 personer från behovsutredningsfasen, och de resterande 7 personerna valdes utgående från deras kunskaper om BIM och informationshantering.

Slutsatsen av diplomarbetet är att behovet av byggnadsinformationsmodeller varierar mellan projekt och faser, så att behovet av en modell måste utredas fas- och projektspecifikt. Det lönar sig att göra en inventeringsmodell så tidigt som möjligt efter att behovet av en modell konstaterats. Modeller ska göras för behoven i den aktuella fasen och för den aktuella projektören och inte för framtida bruk. En modell av byggnadens struktur borde göras av strukturprojektören i projektplaneringsfasen. För att hantera och granska information i början av renoveringsprojekt kunde en utrymmesmodell, som innehåller enbart utrymmen, göras av arkitekten i behovsutredningsfasen.

Nyckelord:	BIM, inventeringsmodell, informationshantering, byggnadsrenovering, underhåll av modeller, utgångsinformation
Språk:	Engelska

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This master's thesis has been written for Senate Properties. I wish to thank Senate Properties for the the possibility to write my thesis about an interesting topic in an inspiring work environment. I would like to thank Auli Karjalainen for advising and instructing me in this project. Special thanks goes to Professor Vishal Singh at the Aalto University for constructive comments and a close involvement in the writing of the thesis. I also want to thank BIM specialist Juho Malmi and master's thesis worker Johanna Oikarinen for good discussions about the thesis. I further wish to thank all the interviewees and all the participants in the workshop, without whom the research could not have been done. Finally I wish to thank my family and especially my girlfriend Natalie for all the support you have given me.

Helsinki, April 16, 2014

David Helander

Abbreviations and Acronyms

BIM	Building Information Modeling / Model
COBie	Construction - Operation Building Information Exchange
COBIM	The Common BIM Requirements
MEP	Mechanical, Electrical, and Plumbing
FM	Facilities Management
IFC	Industry Foundation Class
Inventory model	Model of an existing building created prior to a renovation project
Model	In this thesis a synonym for building information model

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Chapter 1

Introduction

Information management is a major task for all companies. Information loss is a big problem in many industries, especially in the construction industry. This is due to the fact that each construction project is unique with new stakeholders, aims, processes, and standards. One way to improve the information sharing and reduce the loss of information is through Building information modeling, BIM. BIM is the process of creating and using digital models for design, construction and operations of building projects (*The business value of BIM: getting Building Information Modeling to the bottom line* 2009, p.4). This thesis studies how BIM can be used to improve information management in the beginning of renovation projects. The thesis is written for Senate Properties which is a government owned enterprise under the aegis of the Finnish Ministry of Finance.

1.1 Background and problem statement

It has been shown that the building life cycle is divided into two parts which are (1) design and construction of a building and (2) facilities management (FM). These phases of the building life cycle are currently dissociated from each other in the processes of building management (Vanlande, Nicolle, and Cruz 2008, p.1). Not only is the construction process detached from the maintenance process, also the information flow between the phases needs to be improved. One problem is that the minimum information requirements in the beginning of a renovation project is not understood very well. It has been shown that data requirements are not defined clearly. Thus, there is a need to clarify and understand who should provide the construction project data for creating an inventory model, and when (Becerik-Gerber et al. 2012, p.8).

A problem that still remains unsolved is: who should maintain a building model between projects and how should the costs be distributed between departments of a FM company (Azhar, Khalfan, and Maqsood 2012, p.12). The use of BIM thus needs to become more standardized and guidelines have to be set up for implementation of BIM in all phases (Azhar, Khalfan, and Maqsood 2012, p.12).

The possible use of models in condition surveys have also been found as a topic needed to be researched (Haavisto 2013, p.71).

1.2 Aim, objectives, and research questions

The aim of this thesis is to assess alternatives for using building information models to manage initial information in major building renovation projects.

The main objectives of the thesis are: (1) to find the useful minimum information required in the early phases of major building renovation projects, (2) to evaluate how BIM can be utilized by asset managers to ensure that the initial information for a renovation project is correct and up to date, and (3) how BIM can be effectively utilized to improve the management of information for renovations projects at Senate Properties.

The goal is to transfer the minimum amount of information to each phase of the project but still include all relevant information, also called the useful minimum principle(Hietanen and Lehtinen 2006, p.1).

The research questions that are to be answered in this thesis are:

1. What information is needed in the early phases of a renovation project?
2. How can this information be managed with BIMs?
3. How is value added to the facility owner through the use of BIM in these stages?
4. When and how should inventory models be created?
5. How should building information models be maintained?

1.3 Methodology

The research is based on literature, semi-structured interviews, and documentations of projects at Senate Properties. In total 21 semi-structured interviews have been conducted with people from (1) three renovation projects at Senate Properties, (2) members of the Workplace and Facility Solutions team at Senate Properties, and (3) BIM-experts associated with Senate Properties. A workshop was conducted to validate the findings.

1.4 Boundaries

This thesis focuses on the strategic decisions about the information requirements and management for renovation projects. Hence, the thesis will not go through detailed building information needed at the operational level. The optimal content of an as-built model will not be research, but only the information requirements for a renovation project are investigated. Neither will the focus be on annual or other smaller renovations but only on major renovations. The thesis is also case specific, focusing on one facility owner and their organizational processes.

1.5 Prior research and related projects

This thesis is a part of the Model Nova work package in the development program Built Environment Process Re-Engineering (PRE) lead by RYM Oy. The purpose of Model Nova is to research how BIM can add value to both the client's and the other stakeholders' decision making processes. Model Nova also includes development of work processes and information systems. The target of the PRE program is to develop business and management models using BIM, based on sustainable development.

A research project called ELVYKOR (Elvyttävä Korjausrakentaminen, eng. Revitalizing Renovation), which ended in 2013, had the objective to clarify the usefulness of COBIM (the Finnish common BIM requirements) in renovation projects. Results from the research have been considered in this thesis (Valtonen 2013). A report about the maintenance of a buildings technical information written at Senate Properties and further presented and reviewed in section 3.1 serves as a basis for this thesis (Alatalo 2009).

1.6 Structure of the thesis

The remainder of this thesis is organized as follows. Chapter 2 contains a brief review of literature related to the subject. Chapter 3 presents the structure and the processes of Senate Properties, followed by a presentation of the research methodology in Chapter 4. In Chapter 5 are the three cases presented in more detail and the gathered information is laid out. The information is then analyzed in Chapter 6. In Chapter 7 are the results of the analysis discussed and the recommendations for Senate Properties presented. In Chapter 8 are the conclusions of the thesis summarized. The structure of the thesis is shown in Figure 1.1.

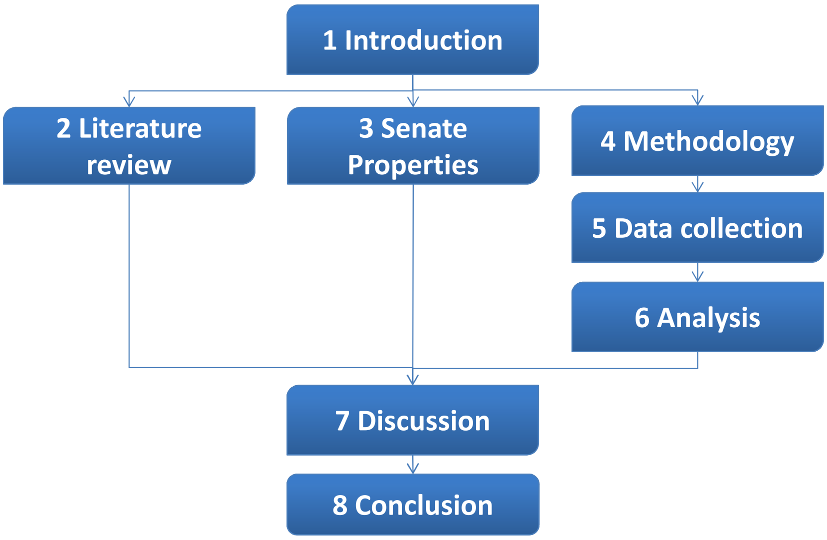


Figure 1.1: Thesis structure.

Chapter 2

Building Information Modeling (BIM)

This chapter presents an overview of BIM-literature related to the thesis topic. The definition of BIM is concluded and possibilities of BIM for different uses are presented.

2.1 The definition of BIM

BIM is an acronym for Building Information Model or Building Information Modeling. It is thus possible to look at BIM from several points of view (Aranda-Mena et al. 2009, p.2). BIM can be seen as a software application ("M" in BIM stands for "Model") (Volk, Stengel, and Schultmann 2014, p.111). BIM can also be seen as a process for designing and documenting building information ("M" in BIM stands for "Modeling") in addition to being a software application (Azhar 2011, p.242). A third way to look at BIM is to see it as a whole new approach to the whole building life cycle requiring the implementation of new policies and contracts (Azhar, Khalfan, and Maqsood 2012, p.1; Eastman et al. 2011, p.13).

BIM as a model is defined by the National Institute of Building Sciences in the following way:

> A BIM is a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle from inception onward. A basic premise of BIM is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract,

update, or modify information in the BIM to support and reflect the roles of that stakeholder. (*National building information modeling standard: version 1-part 1* 2007, p.21.)

A building information model (BIM) is characterized by four features: (1) building components represented by objects with attributes and rules specifying what they are, i.e. a window is a window and can only be attached to a wall; (2) consistent and non-redundant data meaning that changes made in one view leads to changes is all other views as well; (3) components include data that describe how they behave for use in analyses and work processes; and (4) coordinated data so that all views will be represented in a coordinated way (Wijayakumar and Jayasena 2013, p.4). Figure 2.1 shows the difference between how a human and a computer perceive an object made in different CAD applications. Of these only the last one is a BIM.

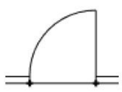
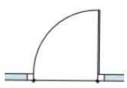
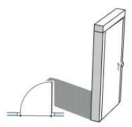
	Method	Human interpretation	Computer interpretation
	Drawing (Scanned)	Door	Pixels
	Drawing Information model	Door	Lines / Arcs
	Geometry Information Model	Door	Surfaces / Elements
	Building Information Model	Door	Door

Figure 2.1: The difference between a human and a computer interpreting data (translated from Hietanen 2005, p.30).

In a similar way it is logically possible to proceed with models and check, which are BIMs and which are not, for example, the following list by Eastman et al. (2011): (1) models that contain 3D data only and no object attributes; (2) models with no support of behavior; (3) models that are composed of multiple 2D CAD reference files that must be combined to define the building; and (4) models that allow changes to dimensions in one view that are not automatically reflected in other views (Eastman et al. 2011, p.35).

A model can be used for many purposes such as visualization for a client or for making shop drawings for fabrication, which can automatically be generated from the model. It can also be used for cost estimation, which is the process of integrating the object attributes from the 3D-model of the designer with the cost information from a database of the estimator (Tiwari et al. 2009, p.1). Models can further be used for construction sequencing by managing material ordering and delivery schedules, clash detection between designs of different disciplines, energy and other analyzes and simulations, and facilities management including space planning and maintenance operations (Azhar 2011, p.242-243). Figure 2.2 shows the different models used during the construction project and the building life cycle.

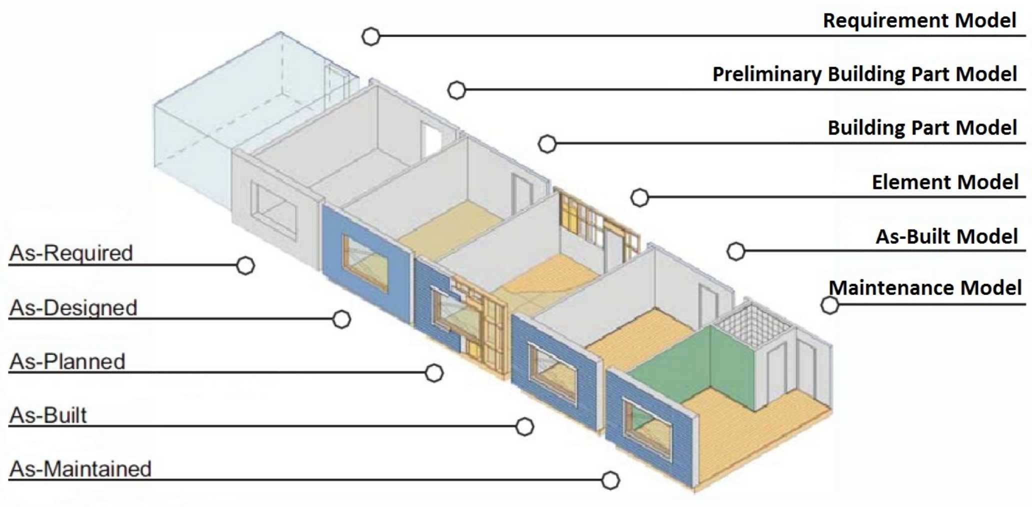


Figure 2.2: The use of BIM in different phases (modified from Penttilä, Nissinen, and Niemioja 2006, p.28).

When a model is created a model description document should be written. The document describes the content, the purpose, and the level of detail of the model. The document is published parallel to the model and has to be updated when any changes are made to the model. (Henttinen 2012, p.10.)

Information to be managed with BIMs can be stripped down to the useful minimum as shown in Figure 2.3. The useful minimum principle means that only the core and most important information should be transferred between phases or applications. The boundary conditions are (1) what information is needed, (2) what information is created, and (3) what information is supported by the applications and transferable. The information can further be scaled down by asking what must be available, what should be available, and what information would be nice to have. (Hietanen and Lehtinen 2006, p.3.)

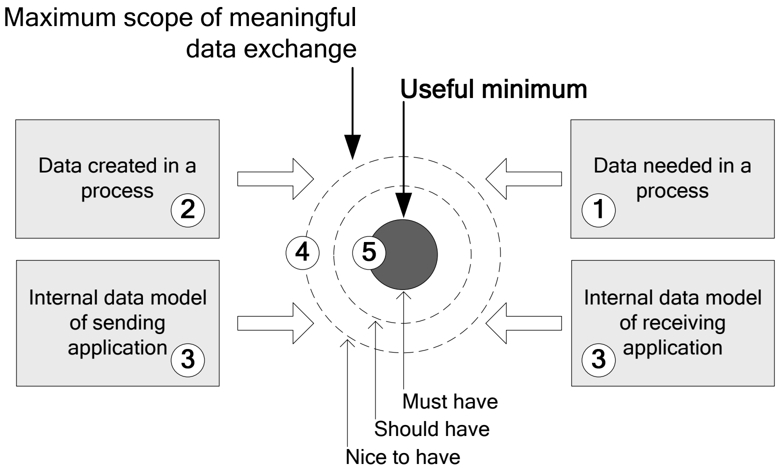


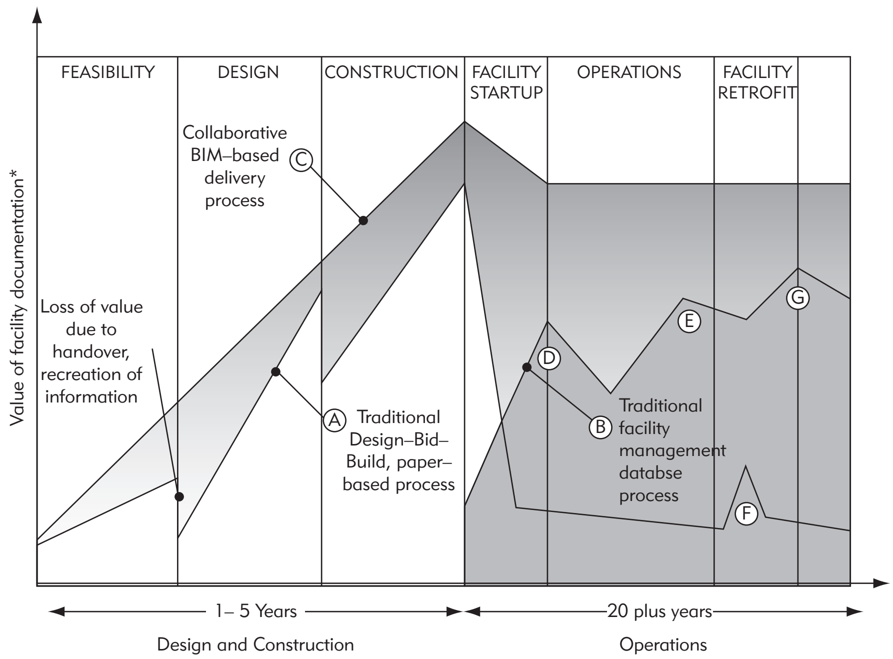
Figure 2.3: The useful minimum principle (Hietanen and Lehtinen 2006, p.3).

2.2 BIM for facilities management

The use of BIM can be highly beneficial for facility managers. The information from a construction project stored in a BIM-database could be used by facility managers in many ways, such as quality control and assurance, marketing visualization, energy management, maintenance and repair, component localization, and space management. For this to be technically possible, the building information needs to be integrated or compatible with the FM information systems (Becerik-Gerber et al. 2012, p.1). Currently the required data is fragmented between systems, or the data is transferred manually from system to system after the building hand-over (Becerik-Gerber et al. 2012, p.1). Facility management systems have been on the market for a long time and they are widely used. Either BIM should prove itself more beneficial for FM than these systems, or BIM has to become compatible with the existing systems (Arayici, Onyenobi, and Egbu 2012, p.6).

The demand to use BIM in a project has to come from the owner (*The business value of BIM: getting Building Information Modeling to the bottom line* 2009, p.5). Thus, the benefits of BIM for the owner has to be shown. One benefit of BIM in projects is that information is better saved and not continually lost between phases as in usual construction projects, seen in Figure 2.4. This is a result of improved cooperation between stakeholders which is one of the goals of BIM (Schlueter and Thesseling 2009, p.2).

BIM should be seen as an asset for facility managers. To maintain the value of the model, the model should be continually updated and maintained (Becerik-Gerber et al. 2012, p10).



(A) Traditional single-stage drawing-based deliverables, (B) traditional facility management database system, (C) BIM-based deliverables throughout the project delivery and operation process, (D) setup of facility management (FM) database, (E) integration of FM with back-office systems, (F) use of "as-built" drawings for retrofit, and (G) update of FM database.

Figure 2.4: Information created and lost throughout a project (Eastman et al. 2011, p.153).

The model can improve the building value in many ways but it is difficult to measure the added value. Bakis, Kagioglou, and Aouad (2006) list the following reasons why it is so difficult to measure the benefits of information systems:

- they do not directly lead to identifiable performance improvements,
- they can lead to major organizational changes which can be seen as the real source of improvement,
- the benefits of information systems evolve over time,
- different objectives of different stakeholders,

- change resistance leading to lower ratings of system,
- misuse of systems leading to lost benefits, and
- difficult to separate the benefit of one system from linked systems (Bakis, Kagioglou, and Aouad 2006, p.2-5).

In a study made by McGraw Hill (2009) 70% of owners report positive ROI from BIM. In the study the participants suggested that lower project costs and better project outcomes are reasons to use BIM. (*The business value of BIM: getting Building Information Modeling to the bottom line* 2009, p.7.) The following benefits of BIM can be found for Facility managers: (1) early design assessment to ensure project requirements are met; (2) operations simulation to evaluate building performance and maintainability; (3) more reliable cost estimates and reduced number of change orders leading to lower financial risk; (4) better marketing of project through walk-though animations and 3D-renderings; and (5) better management of building information (Eastman et al. 2011; Reddy 2011; Azhar, Khalfan, and Maqsood 2012, p.7). The use of BIM for managing maintenance history and the benefits of models in public-private-partnership-projects (PPP-projects) have also been researched (Buddas 2011, Mäläskä 2011).

In a report about BIM for managing the Sydney Opera House (2007) the following BIM functions are stated to be beneficial for facilities management processes: (1) finding the responsible person when an element fails; (2) data mining for finding objects with different properties; (3) managing maintenance history; (4) locate building parts; (5) query vacated space; and (6) simulate and visualize the effect of taking a service out of commission. (*Adopting BIM for facilities management: Solutions for managing the Sydney Opera House* 2007, p.10.) In the report it is suggested that the IFC-format should be used in models for FM while it is a standardized and open format making the data more future-proof (*Adopting BIM for facilities management: Solutions for managing the Sydney Opera House* 2007, p.18).

In the COBIM part 12, which focuses on facilities management, model maintenance is considered as well. Guidelines for the model maintenance should be made for each property describing responsibilities, procedures, and tasks (Jokela, Laine, and Hänninen 2012, p.17). The process for updating BIMs can be seen in Figure 2.5.

The model updates can be divided into two groups: (1) project updates and (2) periodic updates. A project update occurs when a building is renovated. The existing model should then either be updated before the project in the process of creating an inventory model or after the project based on an as-built model. If a small change is made to the building is it not necessary

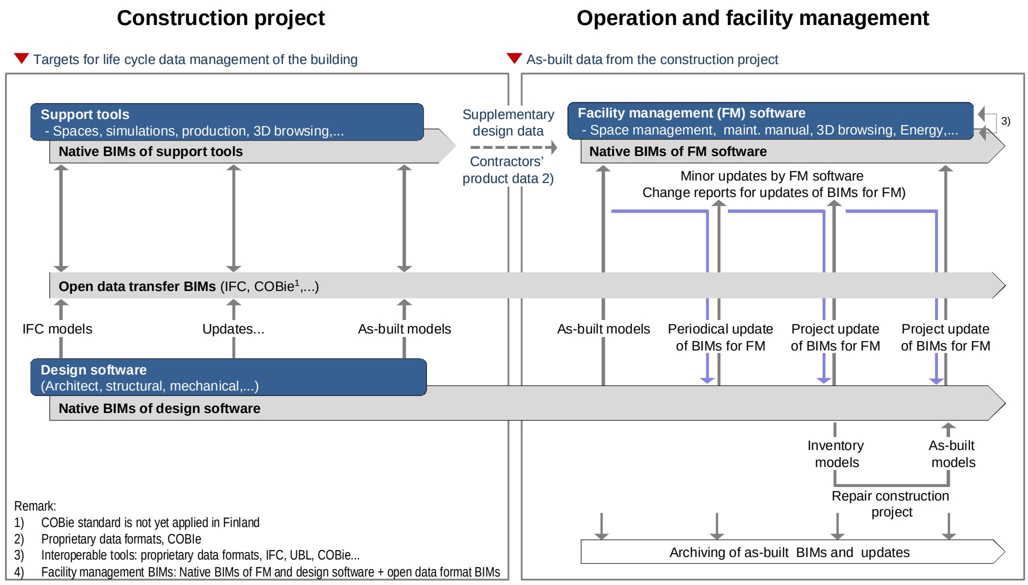


Figure 2.5: BIM management process during the building life cycle (Jokela, Laine, and Hänninen 2012, p.7).

to immediately make the changes in the model. Instead should periodical updates be made to make sure the model is up-to-date and to avoid interoperability problems. The need for a periodic update should be assessed every three years (Jokela, Laine, and Hänninen 2012, p.17). Even though a small change in the building is not directly moved to the model it is highly important to make a change report. The report is needed when the changes are to be made to the model in the periodic update. When models are updated quality assurance is highly important. Quality assurance of BIM is discussed in COBIM part 6 (Kulusjärvi 2012).

2.3 BIM standards

For information exchange between proprietary BIM software with different data formats, a standard data format called the Industry Foundation Class (IFC) has been developed. The standard has been developed to improve the communication, cost savings, productivity, and quality of data throughout the building life cycle (*BIM standards* 2014a). IFC includes object specifications making the attributes of the model objects transferable between BIM applications (Vanlande, Nicolle, and Cruz 2008, p.1). The development of IFC started in the 1990's. The latest version is IFC4, but the commonly used version is still IFC 2x3 (*BIM standards* 2014b).

Another important development for information exchange is the IFC Model View Definition (MVD) (*BIM standards* 2014a). MVD defines a subset of the IFC schema which is needed to meet the exchange requirements. Existing MVDs are Coordination View Version used for clash checking of models in the design phase, Structural Analysis View, and Basic FM HandOver View used for transferring information to the building maintenance phase.

For collecting and transferring the needed information for the building maintenance phase the Construction - Operation Building Information Exchange (COBie) standard has been developed by the U.S. Army Corps of Engineers (*COBie standard* 2014). The idea of COBie is to gather the data as it is created throughout the construction project instead of searching for it prior to handover. Designers provide the information they have, the contractors provide theirs, and the component manufacturers provide data about their components and enter it into a model. In a global first, UK government has set up a goal to require information corresponding to the COBie-standard in all governmental construction projects by 2016.

The Finnish Common BIM Requirements 2012 (COBIM) are a series of 14 parts covering the whole life cycle of a building (Henttinen 2012). COBIM is a standard that sets the minimum requirements for modeling and the information content of models. COBIM is intended to be used in all construction projects where models are used. In addition to this standard, project specific modeling requirements should be included in the project contract.

2.4 Renovation projects and BIM

BIM can also be used in renovation projects. This section briefly discusses the processes and challenges in renovation projects, and the solutions using BIM are presented.

2.4.1 Renovation projects

A renovation project involves the same phases as the construction of a new building. The process starts with an evaluation of the need for a renovation. The need evaluation is followed by the conceptual design phase, where the initial data is gathered, the need for condition surveys is concluded, and alternative renovation possibilities are evaluated. (Palomäki, Olenius, and Nissinen 2010, p.14.) In this phase a project plan is written and the scope and the budget for the project is set.

The next phase is the design phase. One of the key characteristics of a renovation project is that the designs will be specified throughout the project when more information is available. Thus, the meetings at the work site and the design changes made there are highly important. (Palomäki, Olenius, and Nissinen 2010, p.15.) After the design phase the construction work is planned and started.

The reason for renovating a building is that it does not meet the user's needs. This can depend on the aging of the building, or faults done in the design, construction, or use of the building. The aging of the building is not directly related to the age of the building but rather on the usage and the user's needs. The aging can be divided into the following categories: (1) technical aging, (2) functional aging, (3) economical aging, and (4) locational aging. The faults can similarly be divided into the categories (1) functionality faults, (2) experience faults, and (3) technical functionality faults. (Murtomaa 1996, p.372.) To make the decision about what is to be done in the renovation, information about the building is needed. If enough information is not available the decisions made in uncertain conditions may lead to added risks in the project. (Murtomaa 1996, p.372.)

Renovation projects usually face other challenges than new construction projects. Among these are: (1) physical constraints due to current building condition, e.g. limited space or capacity limitation of systems; (2) limited work area; and (3) uncertainty about current building condition (Mitropoulos and Howell 2002, p.179). To reduce the impact of these problems the potential threats should be discovered as early as possible. Thus, the current condition of the building has to be known in the beginning of the design phase. Other risks in the project have to be assessed as well, such as budget and schedule constraints. The project team members should be chosen as early as possible. A team should be chosen so that they can together evaluate the designs. It should be done as early in the project as possible because the possibility to make changes are bigger in the beginning of the project. (Mitropoulos and Howell 2002,p.184.)

In the Finnish construction industry the following problems have been found:

- lack of decision-making process,
- lack of time for planning,
- difficulty in updating construction regulations,
- users do not known what they need,
- lack of trust,

- lack of risk assessment,
- resistance to use of IT, and
- lack of change management (Naaranoja and Uden 2007, p.858).

Trust between the project stakeholders, LEAN-processes, and knowledge management, would reduce these problems and improve the profitability of renovation projects (Naaranoja and Uden 2007, p.858). LEAN-processes mean reducing the share of non value-adding activities and focusing on controlling the complete process (Koskela 1992). The LEAN-principle was first developed for manufacturing but has been concluded to potentially have a great impact on the construction industry as well (Alarcón 1997).

Even though renovation projects might require more effort than constructing new buildings renovations are preferable over demolition and new build. One reason is that a renovation is in almost all cases both cheaper and less damaging to the local environment. Another reasons is that renovation is usually far quicker than demolition and replacement, making it less disruptive to residents. (Power 2008, p.9.) Also from a sustainable perspective, renovation and life cycle extension of an existing building appears more favorable than demolition followed by a new construction (Thomsen and Flier 2009, p.10).

2.4.2 BIM in renovation projects

The use of BIM in renovation projects have been found beneficial in many cases, but the usefulness of a model is still to be evaluated case specifically. Models are especially beneficial when designing new structures, but models are also useful when designing MEP-systems, even though new structures would not be designed (Haavisto 2013, p.66).

In renovation projects inventory models are used. An inventory model is defined as “all historic, survey, measurement etc. data, information [and even knowledge] about an existing building in an accessible and usable format” (Penttilä, Rajala, and Freese 2007, p.6). The inventory modeling requirements has to be clear and sufficient so that the model matches the needs of all designers (Haavisto 2013, p.69). Requirements for how inventory models should be made are discussed in the second part of the Common BIM requirements (Rajala 2012). Another name for an inventory model is initial model.

A prerequisite for modeling the old structures without measuring the whole building, is that the old designs have to be available and be accurate enough. It is extremely difficult to model if the structures of the building are not known, as can be the case with old buildings. This means that if a building is to be modeled the initial information has to be well researched. When an inventory model is used for structural design the accuracy of joints between old and new structures are to be evaluated, especially when it comes to steel structures which requires a high level of accuracy. A way to solve this problem is to make additional measurements. The prerequisite for this is that it has to be well established and documented how accurate the inventory model is and how well the structural locations are known. If the building structure is not accurate enough in the inventory model the structures should be modeled again by the structural designer. (Haavisto 2013, p.67,70.) Also the roles and responsibilities for creating inventory models has to be clarified. It is important to be precise about who is responsible for inaccuracies and who controls the entry data of the model. (Azhar 2011, p.250.) Disagreements can emerge over copyright issues if the ownership rights and responsibilities are not set forth in the contract documents (Azhar 2011, p.250).

For MEP-design in renovation projects it is important to have a model of the old structures. The structures are to be shown well enough in the inventory model and it has to be clear how hidden structures are modeled. The inventory model and the initial information for a renovation project always contain elements of uncertainty. Therefore, the model description document must present which parts of the building are accurately modeled, and which parts are not measured or modeled accurately but only assumed. This is important so that the accuracy of the model can be improved after structures have been opened. The accuracy of the inventory model sets the accuracy of the whole project designs. In the model description document the modeling level of accuracy should always be documented. (Haavisto 2013, p.68-69.) In a renovation project where BIM is used the design begins earlier than in traditional renovation projects, and more resources should be assigned to the design in early project phases. For the project owner to get BIM-based evaluations and analyzes to support the project decisions, the design should start before project launching decisions. (Penttilä, Rajala, and Freese 2007, p.6.)

BIM can have a great impact on the decision-making process in renovation projects. An inventory model can improve data management, project planning, support decision-making, and increase the profitability of the project (Brilakis et al. 2010, p8). BIM also largely affects the sustainability of the renovated building. A model can be used to execute energy simulations in the early stages of the project. This is important because the most important and effective decisions concerning building sustainability are made in the preconstruction and early project phases (Schlueter and Thesseling 2009, p.1; Azhar, Brown, and Farooqui 2009, p.1).

Chapter 3

Senate Properties

The thesis is written for Senate Properties which is a government owned enterprise under the aegis of the Finnish Ministry of Finance. Senate Properties acts as the government's expert on the working environment and working premises. Its services are mainly provided to government bodies. Senate has about 250 employees, a 620 m€ revenue and administers approximately 10,800 buildings with a leased floor area of about 6.5 million m^2.

Senate Properties has a matrix organization divided into business areas and regions as can be seen in Figure 3.1.

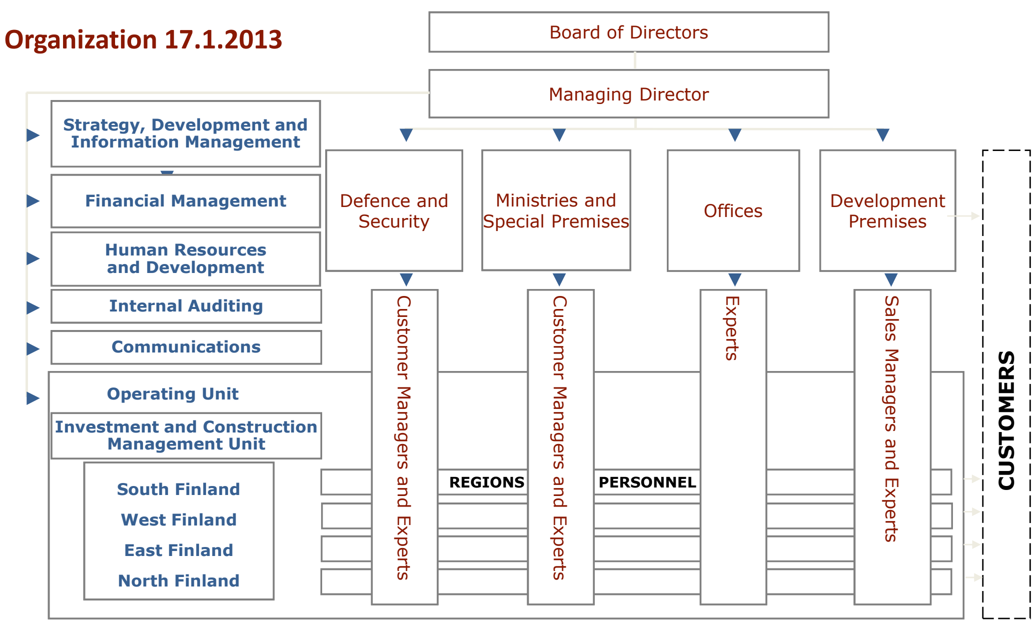


Figure 3.1: Senate Organization.

The four regions "North Finland", "South Finland", "East Finland", and "West Finland" cover the whole country. The business areas are divided into "Defense and Security", "Ministries and Special Premises", "Offices", and "Development Premises". The strategic responsibility lies with the business areas while the operational responsibility lies with the regions.

3.1 Information needs in the processes at Senate Properties

The work at Senate Properties is divided into the processes "Leasing", "Property Management", "Workplace and Facility Solutions", and "Investment Management". In addition to these four processes there are several supporting processes as can be seen in Figure 3.2.

In a report about managing information at Senate Properties, the information needs in the different processes at Senate Properties are described as shown in Figure 3.2.

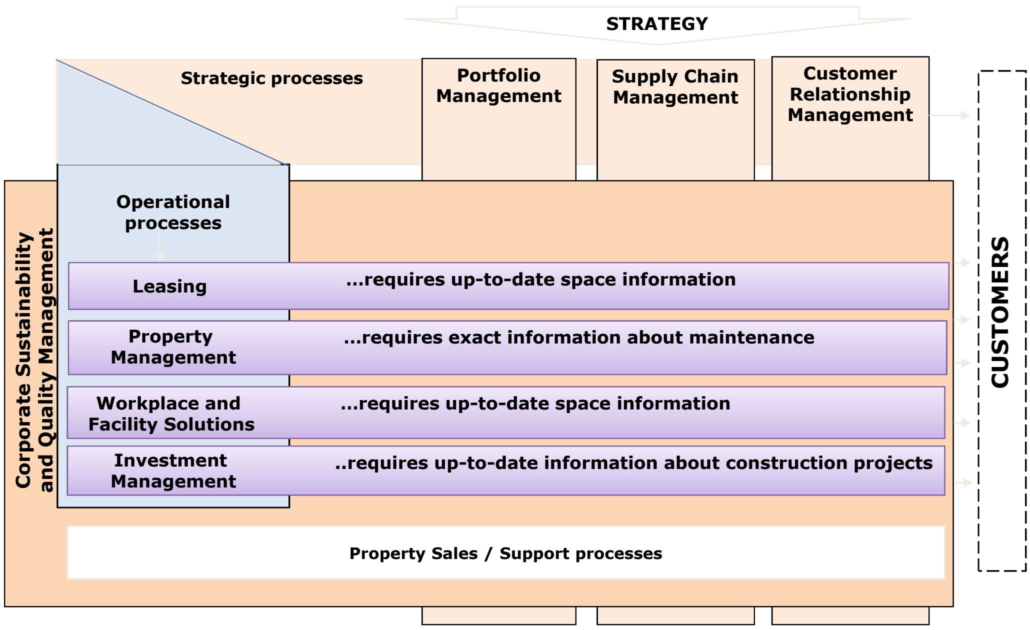


Figure 3.2: Information needs in the processes at Senate Properties (modified from Alatalo 2009, p.16).

In the Workplace and Facility Solutions process as well as in the Leasing process up-to-date space information is needed. In the Investment Management process, information about all previous construction and renovation projects is needed. In the Property Management process, information about building maintenance and technical systems is needed (Alatalo 2009, p.16).

In the report the requirements are set for keeping the technical building information up-to-date. Well documented projects and a comprehensive hand-over of change information after construction projects is a prerequisite for having up-to-date information. In the beginning of a renovation project not all the information is available. The existing information should be correct and it is important to be able to cope with incomplete initial information. The technical information about building systems goes only back to the latest renovation but the structural designs of the building are from the construction of the building. The process of updating the building information separately from a renovation project should prove itself beneficial by saving time through centralized processes and a faster start on renovation projects. (Alatalo 2009, p.12-14.)

Alatalo (2009) also presents the benefits of up-to-date information. The benefits presented in the report are: (1) savings in personnel cost due to time savings, (2) higher leasing incomes due to shorter construction projects, (3) lower risk-premiums in the tendering due to more exact initial information, (4) savings in the facility maintenance, (5) higher prices when selling buildings due to lower risk for the buyer, and (6) effect on the image of Senate Properties as a technological forerunner (Alatalo 2009, p.19).

3.2 The beginning of a renovation project at Senate Properties

The beginning of the process leading to a renovation project at Senate Properties can be seen in Figure 3.3. The process starts with the Workplace and Facility Solutions process and an evaluation of the client's needs. This can be done through a workplace development program where the client's needs and wishes are discussed and compared to potential facilities. Participants in the process are the regional Workplace and Facility Solutions and Leasing team and a business area specific Account Manager.

The Investment Management process starts only after a plan has been developed and the preferable alternative has been chosen. A project manager at Senate Properties is chosen for the project. The project manager leads the conceptual design phase where initial information is gathered and condition surveys are made. Based on the requirements from the client and the technical information gathered the investment management team makes a cost estimate, and a project plan is created. If the plan seems to be feasible

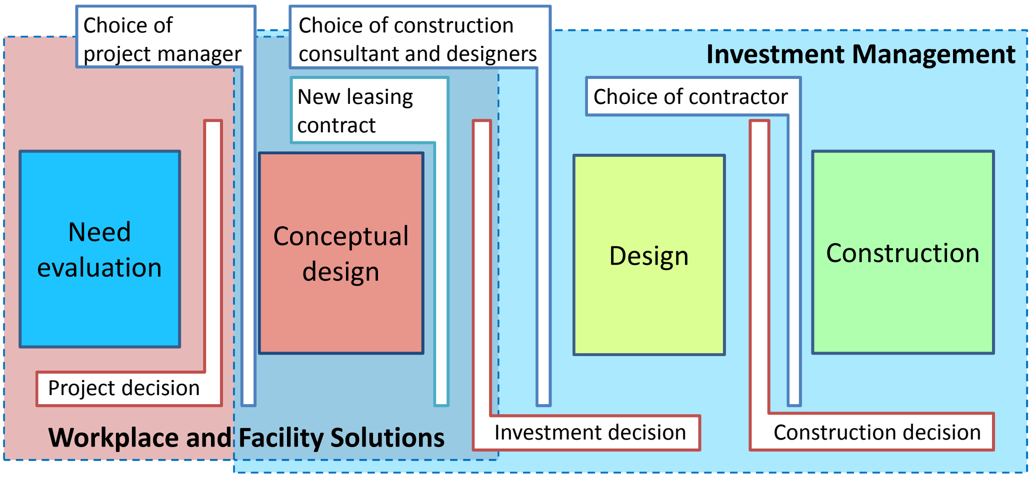


Figure 3.3: The beginning of the investment process at Senate Properties.

and the cost estimate is reasonable a new leasing contract is signed with the client. Based on the existing information an investment decision is then made by the management at Senate Properties. After the investment decision an external construction consultant is hired to manage the construction project. The designers are chosen in this phase as well and the design phase begins. After the design phase a construction decision is made and a contractor is chosen to construct the building.

3.3 Senate information systems

The information systems at Senate Properties and the links between them are mapped in Figure 3.4. Project information is stored in a project database called ProjekTila. Basic information about a new project comes to ProjekTila from a system called HTK where the data is entered manually. In case of a smaller renovation this basic information comes instead from the facilities management system Granlund Manager.

Optimaze is a system used for managing information about the spaces, the area plans, and the utilization rate. The actual facility costs and the personnel costs come to Optimaze from the client. Granlund Manager provides energy information which is allocated to the building area according to the space use. Koki is a system used for managing leasing contracts. From Koki the leasing contracts are imported to Optimaze and linked to the right spaces. The leasing contracts and the floor plans are basic space information existing for most of the facilities managed by Senate Properties. Leasing

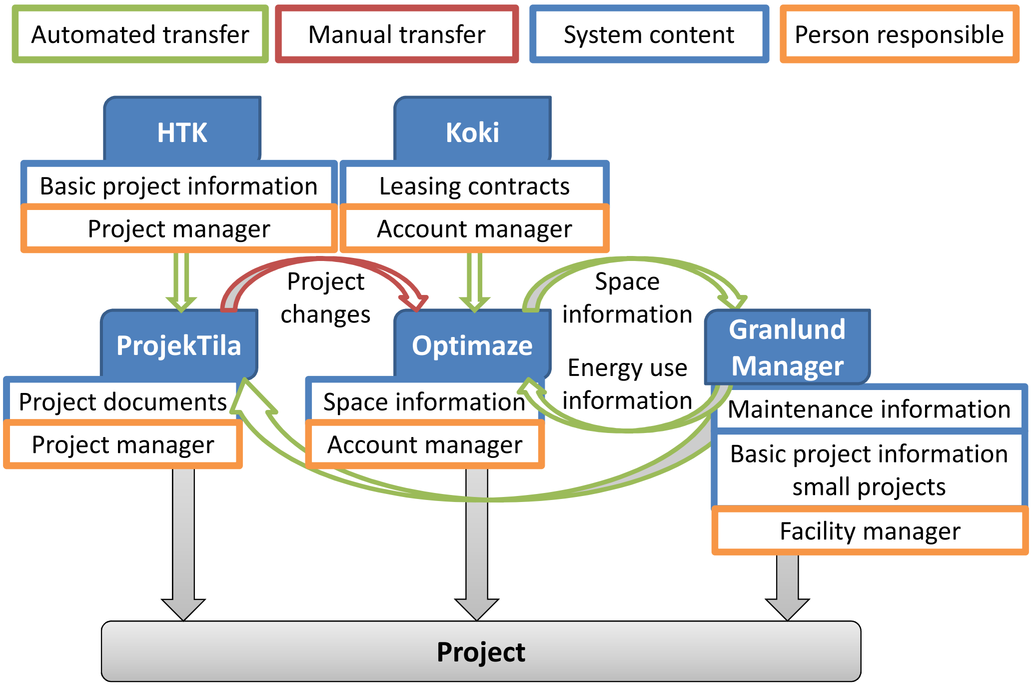


Figure 3.4: Information systems and information flows at Senate Properties.

contracts are made based on the areas in Optimaze. The leased areas are entered into Koki when a new leasing contract is signed. The different areas, including the gross area, can be seen in both Optimaze and Koki. The floor plans used in Optimaze are made based on the architectural floor plans and updated during renovation projects. After a finished construction project the information about the spaces is manually exported from ProjekTila to Optimaze. From the floor plan own objects are created and space bordering lines are drawn. From Optimaze reports about the building use can be extracted, e.g. utilization rate and energy use. From Optimaze space information is automatically exported to Granlund Manager.

3.4 BIM at Senate Properties

BIM is used in all major construction projects at Senate Properties. Since 2000 several BIM-development projects have been conducted.

A development-project currently under progress is a pilot-project called SOME where a maintenance model is being developed in cooperation with VTT. The information requirements of a maintenance model are known but a model has not been developed yet. This pilot project is not focusing on the technical building maintenance, but instead on creating a virtual facility and a condition model to visualize the real-time energy use and thus improve user satisfaction. The facility user can also give space specific feedback to the facility manager and make service requests through the 3D-model. The condition model is made from existing drawings without verification measurements while exact measurements are not needed for visualization. The main point in this case is that the building is recognizable. In the model the current condition of the space properties are shown through the use of sensors giving the users space specific real-time energy use information.

Chapter 4

Methodology

The objective of the thesis is to find out how BIM can be utilized by asset managers to ensure that the initial information for a renovation project is correct and up to date and through this improve the management of information at Senate Properties. The two cornerstones of the thesis are literature on related topics and processes and projects at Senate Properties. The methodology can be seen in Figure 4.1.

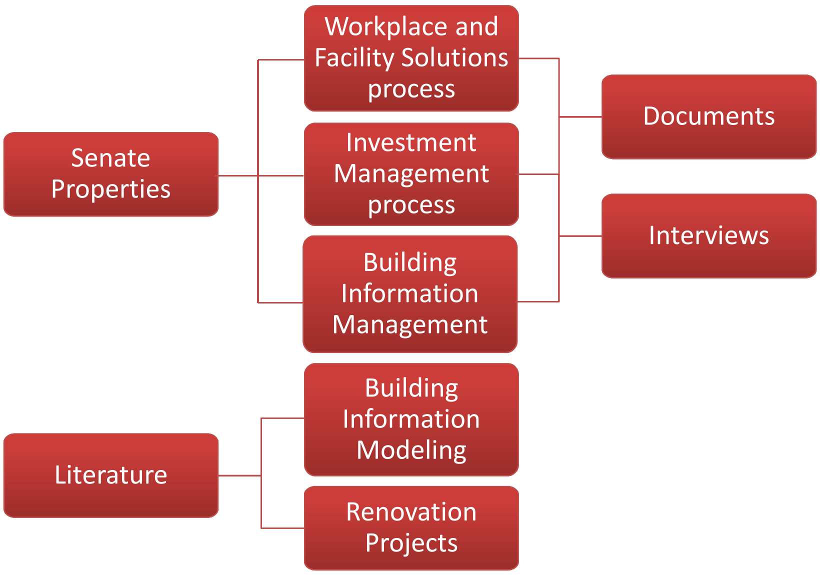


Figure 4.1: Thesis methodology.

The literature used in this thesis is mainly articles found in the database Science Direct. The search for useful literature has been done mainly through Google Scholar using a combination of the search words BIM, Building Information Modeling, buildings, life cycle management, renovation, investment process, and information needs. Literature has also been found through recommendation by the thesis advisors and doctoral students at Aalto University. A third source of literature was the list of references in the articles found.

The research on Senate Properties' investment process has been done through case studies while it is the best investigation method for the benefits of IT-systems (Bakis, Kagioglou, and Aouad 2006, p.281). The information about the cases have been found from Senate Properties project database and through semi-structured interviews with people involved in the projects.

Information about the Senate Properties' Workplace and Facility Solutions process has been found through semi-structured interviews and from different information systems at Senate Properties.

Senate Properties' information management and building information modeling have been researched through reports, documentation, and semi-structured interviews with experts.

4.1 Choice of cases

The cases were chosen from a list of projects that have taken place during the past few years based on the following criteria:

- office building in the Helsinki region,
- major renovation project, and
- broad use of BIM in several disciplines.

Case 1 was chosen because it was a pilot project for the use of BIM at Senate Properties. Case 2 is a project finished only a year prior to the beginning of this thesis and case 3 is an ongoing project which is in the construction phase when the work with the thesis began.

The information needs in case 1 have been collected from three interviews and the case project program. A project plan were never done for this project. The information needs in case 2 and case 3 have been collected from three interviews each and the cases' project plans.

4.2 Semi-structured interviews

Semi-structured interviews were conducted to find the information requirements in the early phases of renovation projects. The interviews were semi-structured because this method include the benefits of an unstructured interview leaving room for supplementary questions while still being structured enough for the results to be comparable (Bryman 2012).

The interviewees have been chosen together with the advisor from Senate Properties and based on suggestions from interviewees. The aim was to find people with different information needs in the renovation process. The aim of the interview questions was to find the answer to which information is needed by each interviewee and if that information could be managed with BIM. The interview questions template can be seen in Appendix B. All questions were not asked from all interviewees due to their different tasks and varying knowledge about BIM.

The 21 interviews including one group interview were conducted from October 2013 to January 2014. Nine persons were interviewed about the three cases. These are the architect, the project manager, and the construction consultant in each of the projects. Five people from the workplace development process were interviewed about their information needs. Six interviews and one group interview were conducted with experts on BIM and information systems about how BIM could be used to manage certain information and linking BIMs to information systems used at Senate Properties. A list of the interviews conducted can be seen in Appendix A.

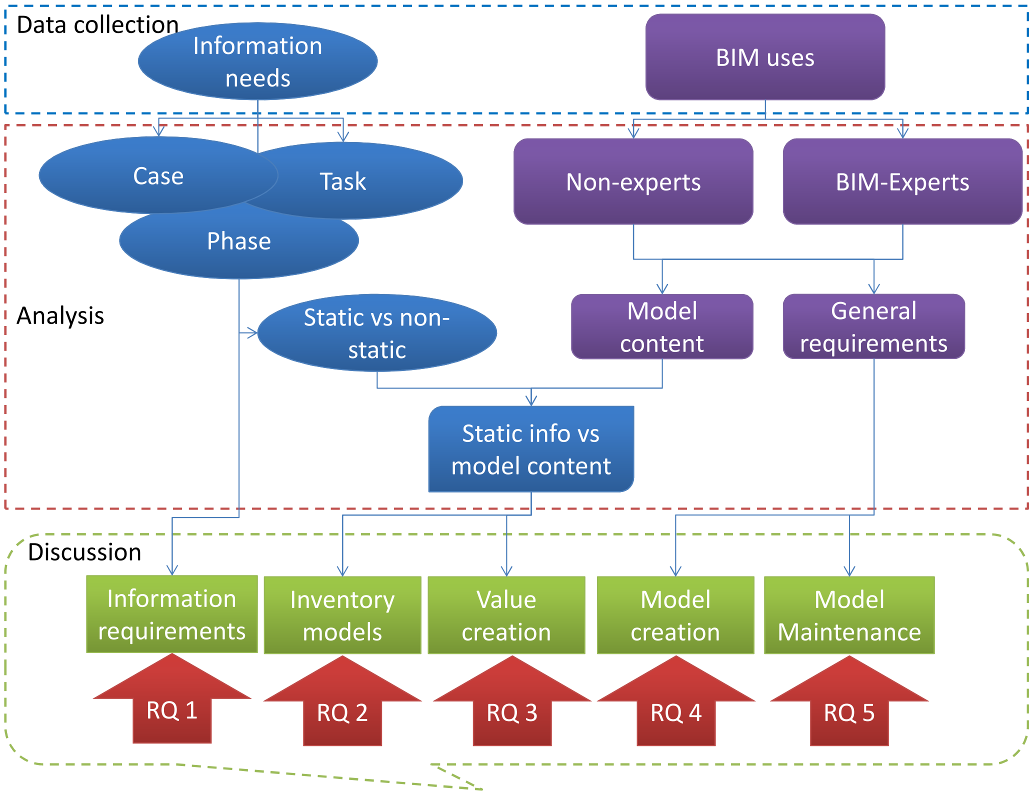
BIM was mentioned prior to the interviews even though it has been found that resistance against change can affect the answer of interviewees making them unwilling to give all the needed information (Larsson and Nae 2011).

4.3 Data analysis

Notes from the interviews formed the basis for the data analysis. The collected data about information needs was entered into a spreadsheet-based matrix with the axes interviewee and information needs. The case data was compared between cases so that case specific information could be removed and the information generalized. The data was further compared between tasks to evaluate if clear task dependence existed in the answers.

The data from the case interviews was then compared to the data from the Workplace and Facility Solutions phase to see what information is needed throughout the process and what information is needed only in one of the phases. The data was then summarized in one table including all renovation project information requirements. The information needs were further divided into static and non-static information depending on the needed frequency of updates. Static information is defined as information that change seldom or can be seen as one time events. Non-static information on the other hand change often or even continuously.

The data about BIM possibilities was similarly mapped in a matrix with the axes interviewee and topic. The answers were compared across interview groups and reasons for disagreements were evaluated. The static information needs were then compared to the perceived optimal inventory model content. The structure of the analysis can be seen in Figure 4.2.



RQ = Research question

Figure 4.2: Analysis structure.

4.4 Validation workshop

A workshop was conducted in March to validate the findings. 10 experts were invited to the workshop and 8 attended. The invited persons where chosen among the interviewees based on their knowledge about BIM. A list of people attending can be seen in Appendix C. The workshop was video recorded for future research purposes.

Chapter 5

Data collection

5.1 Case 1

5.1.1 Presentation of the case

The project planning phase of case 1 began in 2005. The construction phase began in August 2007 and the renovation was completed on schedule in December 2008. The gross area of the building is 23 000 m^2 and the volume is 73 000 m^3. The project was first intended to be a surface refurbishment project which led to an investment decision of 6 m€. When the tenants started looking for new facilities the project changed through fast decisions in the project planning phase into a renovation project with a budget of 31 m€ and a new investment decision in March 2007. The final costs were 38 m€. The biggest single reasons for the higher costs were the users' change orders, additional procurement, modifications of the curtain wall, and greater changes to the building foundation than expected.

A major reason for the renovation was that the building had been voted the ugliest governmental building in Helsinki for years in a row, thus needing an image makeover. Other main reasons were: (1) the tenants' changed space requirements, and (2) a need to renew the buildings MEP-systems. The façade and the foundation were refurbished and the entrance was moved. All information was not available at hand when the investment decision was taken which led to the expansion of the project. The used project delivery system was Construction Management.

BIM was used in the project from the beginning of the design phase by all designers. This project was a pilot project for the use of BIM at Senate Properties. The idea was to make models which could be used in the maintenance phase. This has not been done due to incompatibility with the current maintenance systems. An architectural inventory model was created through laser scanning of the building in the beginning of the design phase. A structural inventory model was done based on two laser scans, the first one after removal of the light structures and the second one after removal of the MEP-systems in the ceiling. Thermal imaging was used to model the heat loss through the building envelope. Models were especially used for fitting of MEP-systems, checking of shafts, and planning of installation order. The models were also used for clash detection between the architectural, the structural, and the MEP-models.

5.1.2 Initial information needed in the project

"You have to know the past to understand the present" is a quote by astrophysicist Dr Carl Sagan which applies to buildings as well as the universe. The case construction consultant (CC1) emphasizes that information about the building history is needed when initiating a renovation project. The project manager (PM1) agrees with this and adds that this applies to both the usage history and the information about how the building was built, i.e. the original designs. From the previous designs the building's gross area and the leased area are to be calculated so that the scope of the project can be understood (Ristolainen 2005).

Information about what has happened in the building during the last 15 years is especially important to know (PM1). This could be renovations or changes, both smaller ones initiated by the client and bigger renovations made by the owner (CC1). PM1 also mentions that what is needed is not only information about what has been done and when it has been done but it is also important to know why the changes and renovations have been done. If, for example a wall has been built, it has to be clear if it was done to improve the stability of the building or simply because the client wanted a space reconfiguration. The designs and the building history are needed to be able to understand how to replace or repair parts (PM1).

In this case, history about the site was also noticed to be of great importance. During the second world war there was a factory on this site which spoiled the soil. When a survey on harmful materials was conducted in the beginning of the design phase of this project, it was realized that great amounts of soil had to be replaced. Also other harmful materials, such as asbestos, were found in the building. There is also often little knowledge about drainage systems and the building foundations generally while these can not be seen. In this case the drainage systems were originally designed but when surveyed it was found out that no drainage systems existed (PM1). General surveys of this kind would rather be done beforehand (PM1). Also surveys on indoor climate and moisture damages are needed to be provided with the initial information (PM1). CC1 adds that this also applies to documented problems that have been detected throughout the years, such as indoor air quality levels and moisture damages.

The project architect (AR1) mentions that in addition to the location of the building parts the designs are also needed for knowledge about the content of the building parts. Surveys also have to be made beforehand to check the content. In this case it was found out that the general insulation thickness was only 7cm in the external walls. PM1 adds that a window renovation done a few years earlier for improving energy efficiency could have been avoided had this information existed while it was not the most effective way to reduce the energy usage. Also the insulation of the foundation walls were inadequate and had to be replaced. When the structure of the building envelope was further analyzed it was found out that the two concrete layers which form a sandwich element were cast together in places and the outer layer had to be spiked away (CC1). Exact measures of the building structure is also needed for designing technical systems. For example shaft width and story heights are needed for evaluation of the free space for technical systems (CC1). This turned out to be a problem in this case where the story height was only 3,19m. PM1 mentions that the current use of technical systems, e.g. what each pipe and electrical wire is used for, is also needed to be known. Wires that are not used should be removed to reduce the amount of burnable material.

The building utilization rate, i.e. the number of work stations compared to the potential amount of work stations or the number of square meters per person, is to be known (PM1). Also the current use of the building (PM1) and the client's satisfaction with the spaces (Ristolainen 2005) is needed, to understand which changes are needed to be made. PM1 adds that in the same way the actual energy use per person and leased square meters are needed to evaluate which changes are to be made. Also the energy consumption history is needed for comparison with the post-renovation consumption (PM1). Overall, as much information as possible is needed in the initial phases of a renovation project (AR1). One problem that was mentioned is that old documents are neither accurate nor up-to-date (PM1). Thus, an evaluation of the accuracy of the existing documents is needed. CC1 points out the fact that if there is a lack of information more surveys have to be made.

In summary we see that the structural properties, especially the building envelope, is of great importance. The space properties are to be known and time and reason for renovations and surveys performed are needed. Also information about the building history is important to have.

5.2 Case 2

5.2.1 Presentation of the case

Case 2 project was completed in December 2012, three months over schedule, after a construction phase of 18 months. The planning started in the summer of 2009 and the contractor was chosen in April 2011. The actual cost were 13 m€ being 1,6 m€ less than budgeted. This office building has a gross area of 8 100 m^2 and a volume of 27 000 m^3.

The reason for the delay was that the leasing contract with one of the users could not be broken and the user moved out three months after the construction phase started which lead to the three month delay in the finishing of the project as well. The reason for the lower costs were a prediction of 15 % higher costs which did not take place due to the financial crisis and the following recession.

The client's space change requirements were the main reason for the renovation project. These requirements involved the building of a conference center and the change of the office environment to be more open and mobile. In the renovation the MEP-systems were completely renewed and the main entrance was moved. The used project delivery system was Construction Management.

An architectural inventory model was created in the beginning of the design phase. Architectural, structural, and MEP-models were used in the project, both for design and clash checking. Use of models to fit the MEP-systems into the ceiling was highly beneficial while there was little room due to the low story height. Models were also used for energy and air stream simulations. Models were partly used at the construction site.

5.2.2 Initial information needed in the project

In this case as well as the previous one information about the building history has been needed. From the project plan it was found that the building age, the site area, the gross area, and the room areas are of interest for the project (Savolainen 2010). These are needed to set the project scope, and thus the schedule and the budget or the project.

The project manager (PM2) points out that previous renovations, which should always be documented, have to be identified in the conceptual design phase (Savolainen 2010). This includes both what has been done and when the changes have been made. Also other documentation should be available for the renovation project, such as condition surveys for general condition estimates (Savolainen 2010). PM2 argues that surveys which have not been made earlier should be made prior to the investment decision. The construction consultant (CC2) adds that especially harmful materials, such as asbestos, have to be found through surveys prior to the start of the project (Savolainen 2010). In the harmful material survey of the basement in this case it was found that the structures had to be replaced due to the high amounts of hydrocarbon in them (PM2).

From the town plan technical connections, such as sewers and water, should be found (Savolainen 2010). The condition of the foundation wall and the surrounding soil is also important to know (Savolainen 2010). Knowledge about the condition of the building envelope is of great importance as seen also in this case. CC2 mentions that in the survey of the external wall condition moisture damage and lack of insulation were found. In the project plan it is mentioned that in addition to this also in the survey of the roofing a water leakage was found. Problems detected prior to the project should be documented and surveys to evaluate the need for actions should be conducted. In this case an unexplained sewer smell had been noticed but no surveys had been done to clarify where the smell came from (Savolainen 2010).

All interviewees agree that the building drawings are needed for structural locations. The story height was a problem in this case being only 3,09m (PM2, CC2). The project architect (AR2) said that due to unclear measurements the story height had to be measured again which also applied for the façade. The condition of the MEP-systems is always needed for defining the scope of the renovation (Savolainen 2010). The level of detail about the MEP-systems depends on the the condition of the systems. In this case no detailed information was needed because the systems were old and had to be completely renewed (PM2).

The use of the spaces and the space modification possibilities are to be clarified (PM2) as well as the area per tenant (Savolainen 2010). When it comes to the current users of the facilities their current leasing contracts has to be known. Otherwise it can have a great impact on the project as in this case when the construction phase was delayed three months due to an unclear contract with a current user (PM2).

In case 2 the structural properties were the initial information requirement mentioned in all interviews. Another important topic mentioned was the space properties, especially the room height which was a problem in this case. Surveys and findings of harmful materials were also seen to be of great importance.

5.3 Case 3

5.3.1 Presentation of the case

The investment decision for case 3 was taken in the summer of 2011 and the construction work started in January 2013. The project is planned to be finished in the autumn of 2014. The gross area of the building is 11 000 m^2 and the volume is 42 000 m^3. The budget for the project is 16,8 m€.

The renovation includes space modifications according to the client's needs, moving of the main entrance, construction of a conference center, and a complete renewal of the MEP-systems. The used project delivery system is Construction Management.

BIM is used in the project for design, clash checking between architectural, structural, and MEP-models, and during the construction phase. BIM is especially used for fitting the MEP-systems into the HVAC-engine room. The building was measured using a tachometer and an inventory model was created by the project architect in the design development phase which prolonged the design phase. The architect was also responsible for the building measurements.

5.3.2 Initial information needed in the project

The building history, in particular the protection of building parts based on building history, is emphasized by the project architect (AR3) and mentioned in the project plan (Savolainen 2011). AR3 adds that the age of the building and the age of the individual structures, both bearing and non-bearing, are needed to determine what should be protected. The construction consultant (CC3) mentions that the boundary conditions given by the national board of antiquities are needed to be known. CC3 adds that renovations, which naturally are a part of the building history, and modifications are also important to be known (Savolainen 2011). AR3 says that information which is needed about these are when the measures have been taken and what has been done.

The content of the building structures should be known, for example if the structures are wooden or contain wood. These structures could contain mold or rot (CC3). The existence of water insulation on the foundation walls have to be investigated as in this case where old isolation was found containing harmful materials and thus needed to be replaced (CC3). The project manager (PM3) as well as the other interviewees mention that surveys for harmful materials are needed, because in this case asbestos, cinder stone, and rotten wood were found in the floors (Savolainen 2011). Also other surveys than searches for harmful materials have to be done before the start of the project. The general condition of the building is for example to be estimated (Savolainen 2011). CC3 mentions that surveys of the façade and windows were done prior to the project and re-done in the beginning of the project due to lack of accurate information. Also surveys on indoor air quality, e.g. high radon concentration and contaminated air, are to be conducted (PM3) (Savolainen 2011).

Usage of energy and also energy losses through heat leakages are to be known to measure the impact of the renovation for improved energy efficiency (PM3) (Savolainen 2011). Both AR3 and CC3 say that problems detected during the use of the facilities such as moisture problems and indoor air problems are to be documented and acknowledged in the beginning of the renovation process (Savolainen 2011). The scope and the location of the problems are also to be identified, such as where water leakages have occurred and which areas are affected by drafts from windows or low air quality (PM3) (Savolainen 2011).

PM3 argues that knowledge about the condition of the MEP-systems is needed, especially the condition of the main lines is to be known to determine which parts are to be replaced and which parts could be saved. For this the age of the systems should be known and also the life length of the systems (Savolainen 2011). AR3 and CC3 agree that space reservations for MEP-systems, especially the size of shafts, always needs to be known. Information about the overall MEP-systems is needed if all parts are not renewed (PM3). This includes machines, materials, shafts, ducts and networks (PM3). CC3 argues that imaging of existing drainage and sewer systems is sometimes needed for evaluation of the need for replacement. Also the location of technical connections to the municipal networks are to be known (CC3, PM3).

Areas of the building, the current use, and the utilization rate are also relevant initial information, needed to set the project scope. (Savolainen 2011) Similarly as in case 1 knowledge about the accuracy of the initial information was found to be of great importance (AR3, PM3).

To conclude, the information about the structures as well as the space properties is seen to be important. A general need is also information about where MEP-systems could be placed, both in the ceiling and in shafts. Renovations are important to remember, and also surveys done, especially findings of harmful materials and moisture damages. The building history and protection of building parts for historical reasons are also seen as critical information.

5.4 Workplace and Facility Solutions

The needed information in the Workplace and Facility Solutions process starts from the needs of the client. In the beginning there is no need for information about the building says one team member (WP3). The needed information depends on the project and becomes clearer during the project (WP3). WP3 adds that the information is often needed fast and the client might want a proposal within a few weeks.

WP4, WP5, and WP2 agree that information about when renovations have been done, what has been done and the scope of the renovations is important to know (*Workplace and Facility Solutions needs template* 2011). WP1 adds that it is important to document renovations after a project ends. It is also important to know about renovations to be done during the next few years and especially during the time of the leasing contract (WP3). WP5 adds that the building age should also be known.

The building structure and structural boundary conditions is necessary information (WP5, WP3). Also the strength of structures are needed (NWP4), e.g. load bearing properties of floors if an archive is planned on the floor (WP1). WP5 mentions that material properties are to be known and also the materials in light structures. Location of structural elements in spaces and the story height is always needed information (WP5) (*Workplace and Facility Solutions needs template* 2011).

WP4 says that the current and the required safety levels are needed to be clarified and WP1 adds that for some clients windows are to be protected up to the height of 4m. There are on the other hand no boundary conditions based on safety levels for the building structures, aside from police buildings (WP1).

WP3 and WP2 point out that knowledge is needed about the current space conditions compared to the requirements set by the client and information about if the required quality level can be reached, e.g. the indoor air quality. WP1 and WP4 agree that information about the indoor climate; e.g. the temperature, air speed, sound level, and indoor air quality; and surveys done to evaluate these properties, is important knowledge at least if the building is not completely renovated.

Especially important for the client is information about the indoor air quality, e.g. temperature, draft, and detected air problems (WP4, WP1, WP3, WP5). WP1 mentions that also knowledge about the space surfaces are important for the clients.

Detected problems are to be documented and later on acknowledged in the workplace development process. Problematic areas and hiding threats, such as location, scope and date of possible water or other leakage have to be known as well as location of harmful materials (WP2) (*Workplace and Facility Solutions needs template* 2011).WP3 says that the history is needed of which surveys have been done and when, which surveys are not done, and which surveys are to be done again. WP5 points out that information about the building condition, e.g. condition of external walls, found through surveys needs to be known. Also information about when the surveys have been done is needed while old surveys have to be redone according to WP5.

WP4 and WP1 mention that the utilization rate of the building, i.e. area per person, is to be known (*Workplace and Facility Solutions needs template* 2011). Positive and negative properties of the spaces based on feedback from the current users needs to be taken into account (WP5) (*Workplace and Facility Solutions needs template* 2011). WP3 points out that space change flexibility and costs that arise from changes is needed knowledge. WP4 says that the length of the leasing contracts of the current tenants are also needed.

WP4 mentions that boundary conditions set by the current HVAC-system capacity is to be known. WP1 and WP5 add that especially the cooling capacity might set up boundaries when the space utilization rate rises. WP5 also says that knowledge about the existing information networks is important and information about which cable is used for what.

All the MEP-systems are not always changed in renovations and thus might information about the systems be needed (WP5). This involves the possibility to protect MEP-systems during a renovation and if it is difficult it might be easier to replace the system (WP2). WP2 also mentions that information is needed about the condition of the MEP-systems, i.e. water pipelines, sewers, thermal system, cooling system, ventilation, and building automation (*Workplace and Facility Solutions needs template* 2011). WP2 and WP5 point out that information about machines is also needed, e.g. age, life length, location, type, and last service. Also information about the building energy efficiency is needed (*Workplace and Facility Solutions needs template* 2011). WP5 emphasizes that the accuracy of documents is important to be understood.

To summarize these interviews it can be concluded that the building structure and on it based boundary conditions is generally seen as important information. So is also the indoor air quality and other space properties. Done renovations and surveys is also commonly seen as important initial information.

5.5 Possibilities to use BIM for managing initial information

In this chapter are the interviewees' comments and ideas about the use of BIM in the early stages of renovation project presented. The results are presented task specific.

5.5.1 Project managers

The inventory model should contain critical structures and visualize the areas affected if a device is taken out of use (PM1). In an inventory model there should not be any guesses and only actual observations or otherwise will the guesses have to be marked as guesses (PM1). PM3 argues that information about the building protection is not necessary in a model when the building is protected as a whole while changes always have to be discussed with the National Board of Antiquities. PM3 continues by saying that it would neither be necessary to enter survey results into the model while reports are enough, but the model could on the other hand contain a link to the report.

PM2 argues that it would not be profitable to create an inventory model before the investment decision. PM3 on the other hand find that it is not easy to say if an inventory model should be created before the design phase. Problems that arise are that it is difficult to measure the building when the building is in use and that the content of the structures is not equal to the designs (PM3). The benefits of a model has to be evaluated for each case separately so that the cost-benefit ratio of the model is good (PM3). Assumptions and way of modeling have to be documented well when making a model (PM3).

PM1 says that the initial information can be managed if a model could be used as a checklist for information needed. PM3 points out that there is currently a lack of some information in the maintenance manual which could perhaps be solved partly with a model but it is not to be forgotten that the importance of documentation is not reduced by using models. PM3 also mentions that the information has to be easily accessible, e.g. all needed information in one database.

The structural designs are usually rather accurate (PM1). A space requirement model based on old drawings could be useful (PM1). A model could also be beneficial if it would exist in the conceptual design phase but it has to be accurate (PM3). PM1 says that energy simulations have to be done before the investment decision and for this a model could be used.

5.5.2 Construction consultants

CC1 argues that an inventory model should contain the building frame while it is usually left. CC3 adds that especially the location of structures are needed for shaft design and also the shaft measurements are needed while they might change for each story, e.g. while masonry walls are thinner in the top than in the bottom. Knowledge about ducts in bearing structures is important but not all ducts in the structures have to be modeled while it is simply not cost-effective (CC3). If the light structures are demolished it is useless to model them if the demolish contract is not calculated based on the model (CC1).

CC3 says that the location of asbestos in structures would be good to visualize in an inventory model and CC1 adds that found indoor air problems and moisture damages also could be in the model. Not all interviewed consultants agreed upon these information needs. CC3 argues that surveys should not be entered into a 3D-model while it is enough to have the results mapped on a 2D-plan. Information about renovation needs or problematic areas should neither exist in the model (CC3).

The building history including repaired parts and renovation history could on the other hand be in the model (CC3, CC1). Also boundary conditions based on building history could be visualized in the model (CC3).

CC3 says that it would not make sense to put all information into a model while it is simply not cost-effective. On the other hand would the existence of information in models reduce the amount of information only documented in reports (CC1). Space specific information would be accurate enough with a link or a reference to the report which should include more detailed information (CC1).

CC1 argues that the inventory model can be done based on old designs but should at least be measured at some points so that the measurements are verified. CC1 adds that if a structural model is done based on drawings it is enough if verification measurements are done without openings of structures. On the other hand is it impossible to measure beams without opening structures which means that beams could not be modeled accurately in early phases (CC1). Thus, it has to be decided at which specific level of detail a structural model is created (CC1).

CC3 points out that it is highly beneficial to create an inventory model while the condition of the building is thus surveyed before the construction phase starts. Otherwise the problems are moved to the construction phase which is seen in the amount of extra work or rework, change requests, and cost of the project. CC2 agrees that it would be good if models could be used more but argues that it might not still be cost-effective while there is not enough knowledge in the industry yet.

The cost-gain ratio of building modeling has to be evaluated for each project separately (CC2). The ratio depends on required level of detail, e.g. what information about the MEP-systems and machines is needed and if it should be in a model (CC3). This on the other hand depends on what the model is going to be used for, i.e. what is going to be done in the renovation and what the owner is going to do with the model (CC1, ICC3). These are questions that have to be answered by the owner (CC1, CC3).

CC1 says that inventory models should be created as soon as possible when the prerequisites are existing. If designs and drawings are not existing then the structures have to be opened which can not be done until the building is empty and not in use (CC1). It thus depends a lot on the existence of old drawings and luckily a lot of old drawings exist but not all changes have been documented (CC1). CC3 agrees that it would be optimal if inventory models would exist before the design phase while it would provide a quicker start to the project. The owner should create the inventory model in the conceptual design phase because the owner would then be responsible for the initial information provided in the model (CC3).

It would be good if a model could be linked to the space management system or the leasing system in the maintenance phase (CC1). This could be used for measuring the utilization rate and managing free spaces (CC1). CC1 also mentions that the model has to be used in the maintenance phase if it is created then and that building models should not be used in the construction phase only but rather in the whole building life cycle. For models to be useful they have to be kept up-to-date (CC2).

5.5.3 Project architects

According to AR3 the information which should be in an inventory model is either space specific or structural. Space specific information that is needed is building history, moisture problems, harmful material findings, and protected parts or areas (AR3). Also pictures of the actual spaces could be linked to these spaces in the model. The structural model should contain at least the bearing structures, the age of structures, and holes in structures especially is it is not permitted to make new ones (AR3). Also AR1 mentioned that information about the structures, i.e. an structural model, would be beneficial because all designers would benefit from this. MEP space reservations, i.e. shaft measurements and space in ceilings, would also be beneficial to have in an inventory model (AR3). The model could also include links to the building history report (AR3).

According to AR1 an architectural initial space model would not give value to the designers in the beginning of the design phase while the spaces are usually changed. Thus, the rest of the initial information apart from the general structural information could be in its current format, i.e. drawings and reports (AR1).

When asked about when an inventory model should be created the answers from the architects differ. AR3 argues that it would be beneficial if an inventory model existed before the project starts if you could trust the accuracy of the model. AR1 says that it would be beneficial if a structural inventory model would be provided when the design phase begins while structural information about the building is always needed. An architectural inventory building part model would also be beneficial if it would be in the same native file format as used by the architect (AR3). AR3 continues to say that a space model could be beneficial even if it would be provided in IFC-format. AR2 on the other hand argues that an inventory model should be created when the designers enter the project. Then the designers could together agree upon the modeling requirements. It would not give much value to have an inventory model provided while the accuracy of this model would be unclear (AR2). In case 3 a part of the design has to be redone due to flaws in the measurement data even though the project architect was responsible for the measurements. It would have been beneficial to laser scan the complex roofing so that the measurements would have been accurate (AR3).

5.5.4 Workplace and Facility Solutions team

Models could be used if investment costs could be calculated from them (WP3). Needed for this is the current building quality level, the required quality level, the cost estimate, and the areas (WP3, WP4). The costs may vary 10% as well as the areas and more exact area calculations could thus be useful (WP3).

Visualization of the building could be used to locate parts while the facility managers change rather often and it is difficult to get to know a building fast (WP1). Another use of models is visualization of alternatives for the clients, e.g. the placing of spaces change frequently during the design and the use of models could be helpful in communicating the changes to the client (WP1). WP5 adds that a 3D model including the terminal devices would be useful for visualizing the spaces for the client. WP3 mentions that pictures for visualizing the property are important in marketing but on the other hand might a whole model provide unnecessary complexity.

WP5 argues that linking of information to a model would be good for building maintenance. WP2 agrees that a model should be linked to the maintenance history and show what has been maintained and what not.

According to WP5 a space model or a building part model would be beneficial in the workplace and facility solution process. While as much information as possible is needed in the process a complete model with all disciplines would be optimal (WP5). WP5 adds that a structural model would be useful also in smaller renovations.

5.5.5 BIM-specialists

The content, the level of detail, and the accuracy of an inventory model depends on what it is going to be used for says two experts (E1) and (E2). E4 says that an architectural model is too specific for MEP-design but a light structural model would be useful. E2 argues that a building frame model would be a better name than a structural model if it would not contain information for calculations but only geometrical and main element properties. E1 agrees that information about the building frame would be good to have in an inventory model. E2 adds that a model should not be too detailed but suitably simple for the planned use and that a specific model enable specific actions. E3 points out that the need for a model always has to be evaluated and that a model should not be created just because it is possible. If a model is created and proven to be useful then the model should be seen as a part of the building which adds to the value of the building (E2, E4).

The cheapest and easiest way to create an inventory model is from drawings (E1, E3). E1 adds that just creating a model out of drawings does not mean anything if it is not fixed to the existing building through verifying measurements. The building measurements can be done through laser scanning or tacheometry (E1). The costs are depending on the choice of measurement and desired level of detail (E1). E1 says that the cost of laser scanning is about 3 € per measured square meter while measurements using tacheometry costs about 1 € per measured square meter. With laser scanning, millions of points are measured giving detailed dimensions of spaces while using tacheometry single points are measured separately giving detailed locations of specific points. A frame model can be created based on old drawings and by making validation measurements using laser scanning of the basement floor to get the accurate location of columns. The columns can then be assumed to continue on top of each other on the upper floors (E3). The level of accuracy should be documented and marked in the model to clarify which information is accurate and which is based on assumptions or old drawings and thus needs to be examined (E4, E3) By showing the accuracy of the model can a clear division of responsibility for the model content be made between the creator of the inventory model and the future project architect if the inventory model is created prior to the project (E3). This requires quality control and documentation of the modeling conditions (E3). It is important to know what is known and what is not known (E3). If an old model exists the process of making an inventory model is to update and check the old model (E3). The cost of a whole inventory model according to the directives in COBIM part 2 is about 10 €/m^2 including laser scanning for a big office building (E1).

E1 says that it would be optimal if inventory models would exist before the design phase while it would provide a quicker start to the project. Building measurements can be made when the building is in use, e.g. laser scanning takes 1,5 minutes per room (E1). In the need evaluation phase should 3D-models be avoided while spreadsheet based programs provide more freedom (E3). Architectural programs can read this information and automatically create spaces or give existing spaces new properties based on these lists (E3).

If an architectural inventory model is created it should be created in a format chosen by the project architect (E2). If the building frame model only contains geometry and main properties it is beneficial to export it as an IFC-model making the choice of software in which the model is created less important (E2). Simple models can generally be transferred in IFC-format while complicated models should preferably be transferred in their native formats to minimize the risk of loosing information (E2). E3 argues that the information should be in an open file-format such as IFC to avoid vendor locks.

It is possible to link information to an IFC-model and the information can be imported with the model to other software (E2). E3 says that if the model includes only links to reports the information is hard to find, update, and read and therefore should the minimum information requirements be in the model as space properties. E4 on the other hand argues that all information should not be in the same model but linked to the model from other programs. They anyway agree on their main point which is that the information should be machine readable (E4, E3). E2 points out that a 3D-model is not significantly more expensive to make than a 2D-plan if the same space heights can be used at each floor. In a 3D-model, problems occurring at multiple levels in spaces above each other would be more easily noticed (E2).

Models could be updated to a newer version every 3 years as said in COBIM part 12 (E2, E3). The native model should be updated and a new IFC-model exported from the native model (E2, E3). The accuracy and the quality control of the updates can be checked through quantity take-offs from the old and the new model or through a comparison between the old and the new IFC-model (E2). E3 argues that it does not matter who performs the update as long as the requirements are clearly stated in the contract. One possibility is that the designers from the last project could keep the models up-to-date during the maintenance phase (E3).

The MEP-design should be started as early as possible to have the possibility to really affect the outcome (E4). An existing model would make it easier to conduct early energy simulations (E4). The needed information from a model for energy simulations covers areas, spaces, space groups, service areas, and space use (E4). In the energy simulation in the conceptual design phase the architects new space model is used. For making this space model an existing frame model would be useful (E4). An old space model would not be useful because the spaces would have the wrong properties (E4).

If the models are created during the maintenance phase they should also be useful then. E4 says that Granlund Manager currently does not support IFC-models but within a few years it will likely do it. E4 adds that currently 2D-plans are imported from Optimaze to which locations of parts and service areas can be manually linked and thereafter showed on the plans. In the group interview it is said that currently a model would not be more useful than a drawing when creating floor plans in Optimaze. Objects from an imported model can not be used by Optimaze but own objects have to be created. It is also said that IFC-support and use of imported model objects is probably developed within a few years. One interviewee says that the requirements for use of models or drawings in Optimaze are areas used by the client, space use, space boundaries, bearing structures. Another interviewee adds that Optimaze does not include volumes and story heights while they are not needed and usually not provided. The level of accuracy of drawings is not marked in Optimaze but the user is told if the drawings are non accurate.

Chapter 6

Analysis

In this chapter the data gathered from the interviews is analyzed for each case and for each of the interview groups. Common information needs are acknowledged and potential disagreements are examined. The building life-cycle phases where these groups are present are illustrated in Figure 6.1.

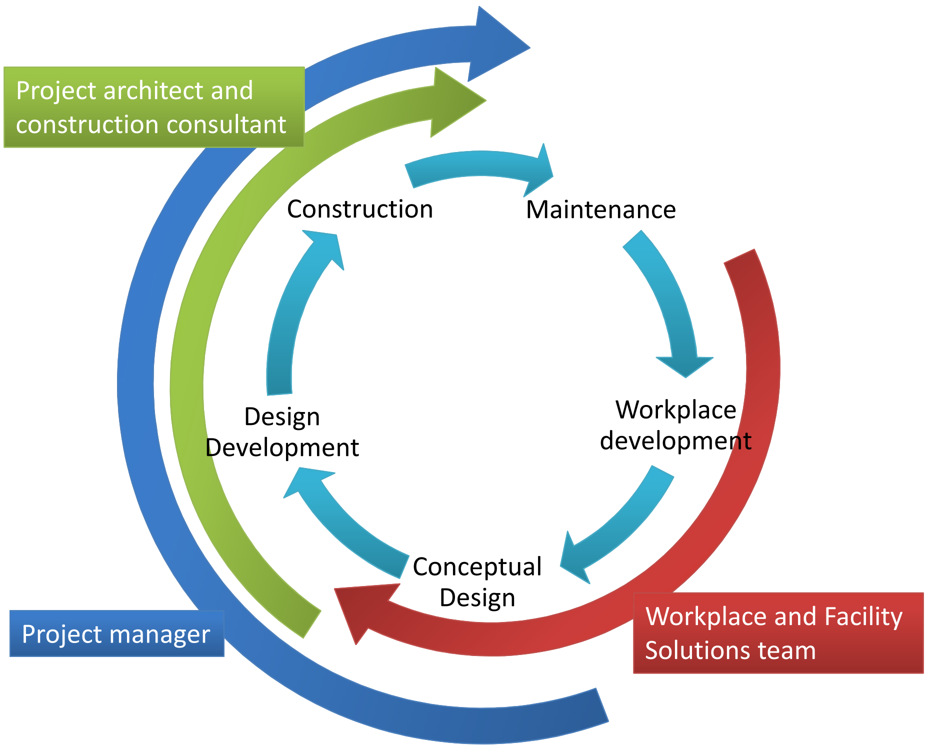


Figure 6.1: Phase of the renovation where the interview group is present.

6.1 Information needs

The information needs mentioned by the interviewees are here analyzed and compared between cases, tasks, and phases. Similar tables are presented in each section. The tables are divided into seven information areas: structural properties, space properties, site properties, MEP-systems, renovations, surveys, and accuracy of documents.

6.1.1 Case dependence

In Figure 6.2 are the answers from the interviews mapped case specifically. As can be seen in Figure 6.2 more topics are mentioned in case 3 than in the other cases. In Figure 6.2 we see a few main areas of structural properties. First of all structural dimensions (1) were mentioned in all the cases. The structural dimensions are for example needed for knowledge about the free space for MEP-systems (2) which is a separate topic mentioned in two cases. The content of the structures (3) is another topic mentioned in all cases. It is mentioned because the insulation and structure of the façade and the foundation wall caused troubles in all projects. Also knowledge about the existence of harmful materials was mentioned in all cases. The last structural topic is the condition of the structures (4) which was mentioned in two of the cases. The difference between the condition of the building and the findings in surveys is that the condition change constantly while the findings of a survey show the condition of one specific place on one specific occasion. Survey results are valid and needed years after the survey has been conducted even though the condition of the building has changed.

Of the space properties we see that the areas (1) and the building use (2) was mentioned in all cases. A case specific information need was the boundary conditions and parts protected based on building history (3) mentioned in case 3. The building in the case is protected and there was a need for additional information and discussions with the National Board of Antiquities. Information about protected parts is only needed if the building is protected. Even though parts of the building are not always protected it is always important to have information about whether a part is protected or not. The fourth space related topic mentioned was the indoor climate (4). Problems detected in the building such as moisture and smell problems, affecting the indoor climate and air quality levels, was mentioned in all cases. User feedback (5) was only mentioned in the case 1 project program.

Regarding the site, the location of municipal networks and the soil condition was mentioned. The soil condition in case 1 was bad which led to

Case	Case 1	Case 2	Case 3
Structural properties 1 Dimensions 2 MEP space 3 Content 4 Condition	[1]story height, [1]shaft size, [1]facade, [1]slab, [1]walls, [2]free space for systems, [3]facade insulation and structure, [3]slab and wall content, [3]harmful materials	[1]story height, [1]facade, [3]structure content, [3]harmful materials, [3]foundation wall and facade structure and [4]condition, [4]roofing condition, [4]general building condition	[1]story height, [1]shaft size, [1]foundation wall, [2]free space for systems, [2]holes in structures, [3]insulation of foundation wall, [3]structure content, [3]harmful materials, [3]existence and [4]condition of wooden structures, [4]general building condition
Space properties 1 Areas 2 Use 3 Protection 4 Condition 5 User feedback	[1]gross and leased area, [2]utilization rate, [2]building history and age, [2]current and previous use, [4]energy use history, [4]moisture problems, [4]water leakage, [4]indoor climate, [4]air quality, [5]workplace satisfaction	[1]gross and leased area, [2]utilization rate, [2]building history and age, [2]space flexibility, [4]moisture and smell problems	[1]gross and leased area, [2]utilization rate, [2]building history, [3]museum boundary conditions, [3]protected parts, [4]energy use and heat leakage, [4]moisture problems, [4]water leakage, [4]indoor climate, [4]draft, [4]radon concentration
Site properties	soil condition	soil condition, location of municipal network	location of municipal network
MEP systems 1 Use 2 Condition 3 Properties	[1]use of each cable and pipe	[2]general condition, [3]detailed information if parts are kept	[2]condition, [2]drainage imaging, [2]which parts to be kept, [2]life length of MEP-systems, [3]detailed information if parts are kept
Renovations	date, why, what	date, what	date, why, what and what not done, enclosures of harmful materials
Surveys	date, findings		date, findings
Accuracy of documents	if not accurate more surveys have to be made, accuracy of information about drainage existence		knowledge about accuracy of documents

Figure 6.2: Initial information needs in a renovation project mentioned case specifically.

unexpected costs.

In all cases were the MEP-systems completely renewed which explain why both in case 2 and case 3 detailed information about MEP-systems are seen to be important only if parts of the systems are kept. The lifetime of the systems and renovations done are similarly needed for making decisions on the replacement of systems. Drainage imaging mentioned in case 3 is a way to check the system condition. Which parts are to be kept depends on the condition of the system and is therefore incorporated into system condition topic.

Regarding renovations as well as surveys, the date and knowledge about what work has been done is seen as important in all cases. The need to record why the renovation was done was also mentioned in two cases. The existence of left enclosures of harmful materials was another case specific information need mentioned in case 3. Information about the existence of left enclosures of harmful materials can be seen as a part of the documentation of what has been done and not done in a previous renovation.

Accuracy of document were mentioned in case 1 and case 3 where inaccurate documents caused problems. In case 1 was accuracy of information about drainage existence mentioned separately while this caused problems in the project. The accuracy of information about drainage existence mentioned in case 1 can be seen as a part of general accuracy of documents.

6.1.2 Task dependence

Figure 6.3 shows the answers of the case interviewees mapped task specifically. Data collected from case documents (project plans and project program) is not shown in this table. Topics that were mentioned in these documents but not in the interviews were the building areas and workplace satisfaction.

Of the structural topics mentioned we see that space reservations for MEP-system (2) were not mentioned by the project managers explicitly but the story height was mentioned. These can be seen as supplementary to each other because the story height is needed for fitting MEP-systems into the ceiling. The façade and the foundation wall can be grouped together under the term building envelope while slabs and walls are grouped into bearing structures. The areas in the space properties (1) was not mentioned explicitly in any interviews but the areas are needed for calculating the utilization rate which was mentioned by the project managers.

The site properties were not mentioned by the architects because their interview answers only concerned the building. Neither were the MEP-systems mentioned by the architects while it is another design discipline. Renovations

Task	Project Manager	Construction consultant	Architect
Structural properties 1 Dimensions 2 MEP space 3 Content 4 Condition	[1]story height, [1]walls, [1]slabs, [3]wall insulation, [3]slab and wall content, [3]harmful materials	[1]story height, [1]shaft size, [1]foundation wall, [1]facade, [2]free space for systems, [3]structure content, [3]water insulation of foundation wall, [3]facade structure, [3]harmful materials, [3]existence and [4]condition of wooden structures	[1]story height, [1]shaft size, [2]holes in structures, [2]free space for systems, [3]structure content, [3]harmful materials
Space properties 1 Areas 2 Use 3 Protection 4 Condition	[2]utilization rate, [2]current use, [2]space flexibility, [2]use history, [3]protected parts, [4]energy history, [4]water leakage, [4]indoor climate	[2]building history, [3]museum boundary conditions, [4]moisture problems, [4]air quality, [4]water leakages, [4]indoor climate	[2]building history, [3]protected areas, [4]water leakage
Site properties	soil condition, location of municipal network	location of municipal network	
MEP systems 1Use 2 Condition 3 Properties	[1]use of each cable and pipe, [2]condition, [3]detailed information if parts are kept		
Renovations	date, what, why	date, why, what and what not done	
Surveys	date, findings	date, findings	date, findings
Accuracy of documents	knowledge about document accuracy	if documents not accurate more surveys have to be made	knowledge about document accuracy

Figure 6.3: Initial information needs in a renovation project mentioned task specifically.

can be seen as a part of the building history which explains why it was not mentioned explicitly by the architects.

The conclusion of the comparison of the task specific answers is thus that the differences between the answers can be explained by the focus of the interviews. No information requirements can be removed based on task biases.

6.1.3 Phase dependence

In Figure 6.4 are the answers mapped phase specifically. In Figure 6.4 we see that there are several differences between the information needs in the analyzed phases (differences marked green and red). The topics marked green complement each other and are added to the combined information needs. The topics marked red are removed from the analysis while they are not seen as initial information or being part of another existing topic.

It can be seen that needs mentioned in the case interviews are based on technical needs such as space for MEP-systems (2) in structural properties and site properties. The interviewees from the Workplace and Facility Solutions phase on the other hand mention needs from the users perspective such as structure boundary conditions and structures in the spaces (1). The strength of the structures (5) was mentioned in the Workplace and Facility Solutions interviews. The strength of structures are to be known for the usage of spaces, e.g. planning locations of archives based on the load bearing capacity of slabs. Knowledge about the strength of structures for safety reasons is only needed in special cases and not generally. Unknown areas are a part of the structure content. The space for MEP-systems depends on the structural dimensions and can be seen as a part of group (1).

The area of the building was not mentioned in any interviews but it is needed for calculating the utilization rate which was mentioned in both phases. (3) Building protection was only mentioned in one of the cases and not in the Workplace and Facility Solutions interviews. (4) Problematic or unknown areas are to be shown also in the spaces, e.g. if the condition or content of parts are assumed to cause problems. (5) Positive and negative space properties were mentioned as needed information in the Workplace and Facility Solutions interviews as well as the quality and safety level of the space (5). The users' thoughts of positive and negative space properties can be seen as a part of the workplace satisfaction which was mentioned in both phases. The required quality and safety level is project specific and not based on the building but on the new user and therefore not initial information.

Machine specific information mentioned in the Workplace and Facility Solutions interviews is specified in the case interviews to be needed only if

Phase	**Cases**	**Workplace and Facility Solutions**
Structural properties 1 Dimensions 2 MEP space 3 Content 4 Condition 5 Other	[1]story height, [1]bearing structures, [1]building envelope, [1]shaft size, [2]free space for systems, [2]holes in structures, [3]harmful materials, [3]structure content, [3]existence and [4]condition of wooden structures, [4]general building condition, [3]foundation wall and facade structure and [4]condition, [4]roofing condition	[1]story height, [1]building envelope, [1]structure boundary conditions, [1]structural elements in spaces, [3]materials, [3]harmful materials, [3]unknown areas, [4]condition of external walls, [4]building condition, [5]strength of structures
Space properties 1 Areas 2 Use 3 Protection 4 Condition 5 User feedback	[1]gross and leased area, [2]utilization rate, [2]building history and age, [2]current and previous use, [2]space flexibility, [3]museum boundary conditions, [3]protected parts, [4]energy use history, [4]heat leakage, [4]moisture problems, [4]water leakage, [4]indoor climate, [4]air quality, [4]draft, [4]radon concentration, [4]smell problems, [5]workplace satisfaction	[2]utilization rate, [2]current use, [2]space flexibility, [2]building age, [4]indoor air quality, [4]temperature, [4]draft, [4]sound level, [4]energy efficiency, [4]moisture damages, [4]problematic and unknown areas, [4]date and scope of water or other leakage [5]workplace satisfaction, [5]positive and negative properties, [5]current and required quality and safety level
Site properties	soil condition, location of municipal networks	
MEP systems 1 Use 2 Condition 3 Properties	[1]use of each cable and pipe, [2]condition, [2]life length of MEP systems, [3]detailed information if parts are kept	[1]cable use, [2]condition, [2]possibility to protect MEP systems during a renovation, [3]machine specific information, [3]HVAC capacity
Renovations	date, why, what and what not done	date, what, documentation, future renovations
Surveys	date, findings	survey history, undone surveys, surveys to be done
Accuracy of documents	accuracy of documents	accuracy of documents

Figure 6.4: Initial information needs in a renovation project mapped phase specifically.

systems are kept and not replaced. The HVAC-capacity can be seen as a part of machine specific information. Protection of MEP-systems depends on what is going to be done in the renovation and is thus project specific and not initial information. It is said that detailed information is needed if parts are kept. What is kept depends on what is going to be done in the renovation and this is thus not initial information.

The reason for and scope of past renovations were of interest in the case interviews and future renovations were mentioned in the Workplace and Facility Solutions interviews. Also future surveys were mentioned in the Workplace and Facility Solutions interviews with a focus on the time period of the leasing contract.

The conclusion of the phase comparison is that in the case interviews the focus were more on technical aspects while the Workplace and Facility Solutions interviewees focused more on the clients' perspective. There are anyhow many similarities between the phases and many information needs can be seen in both columns.

6.2 Information in an inventory model

In this section the answers about the use of BIM from the interviews are analyzed. The information needs analyzed in the previous section are also analyzed from the perspective of BIM use.

6.2.1 Static and non-static information

In Figure 6.5 the needed initial information is divided into static and non-static information. Static information is defined as information that change seldom or can be seen as one time events. Non-static information on the other hand change often or even continuously. Non-static information can either be measured with sensors or through feedback from the facility users. This information can be collected over a longer time and be used for statistics or to present a reason for a renovation, e.g. smell problems which can come from mold due to an unnoticed water leakage. Static information can be collected through surveys or documentation e.g. after construction projects.

The focus of this analysis is on what information could be in a building information model, and thus the information about the site properties is left out. Knowledge about the accuracy of documents are left out of this table because it is a general thought about the information quality and not object specific and thus not comparable with the other information groups.

The information can be divided between the structural properties, space properties, and MEP-systems. In Figure 6.5 we see that most of the structural properties are static and only the building condition is non-static information. The space properties are more evenly divided between static and non-static information. The leased area might change only when new leasing contracts are written or when renovations are done in the building. Problems detected in the building are one time events that can be added to the static information.

	Static information	**Non-static information**
Structural properties 1 Dimensions 2 Content 3 Condition 4 Other	[1]story height, [1]bearing structures, [1]building envelope, [1]structure boundary conditions, [1]structural elements in spaces, [1]shaft size, [1]free space for systems, [1]holes in structures, [2]materials, [2]harmful materials, [2]structure content, [4]strength of structures	[3]structure condition, [3]general building condition
Space properties 1 Areas 2 Use 3 Protection 4 Condition 5 Feedback 6 Renovation 7 Survey	[1]gross and leased area, [2]building history, [2]current and previous use, [2]space flexibility, [3]museum boundary conditions, [3]protected parts, [4]moisture problems, [4]problematic areas, [4]date and scope of occurred leakage, [4]designed air quality and sound level, [4]current quality and safety level [6]renovation and [7]surveys date, actions / findings, reasons, done and not done	[2]utilization rate, [4]energy use history and heat leakage, [4]indoor climate, [4]actual air quality, [4]radon concentration, [4]draft, [4]smell problems, [5]workplace satisfaction future [6]renovations and [7]surveys
MEP-systems 1 Use 2 Condition	[1]use of each cable and pipe, [2]life length of MEP-systems, [2]surveyed condition	[2]condition

Figure 6.5: Initial information needs divided into static and non-static information.

The non-static information can be made static by making surveys while the survey results are one time events which can be seen as static. Because renovations and surveys occur in specific locations they are here included in the space properties. The renovation ad survey histories are static information. Future surveys and future renovations are non-static while surveys can be planned continuously and the actual needed actions are not known until they are taken.

The MEP-systems are here divided into static and non-static information. The lifetime of parts of the systems and the use of the systems do not change between renovations and are thus static. The condition of the existing systems change continuously and is thus non-static. If systems are surveyed the results are static.

The static information could be entered into a model manually and easily maintained. A model including static information needs to be updated due to software version updates and major changes in the building. Changes to the static information can be transferred into the model when the model is updated. The non-static information on the other hand needs to be linked to the model from other systems while entering the data manually would not be efficient. In the SOME project the focus is on managing the non-static data with models. The non-static data will not be further analyzed in this thesis.

6.2.2 Analysis of BIM possibilities

The ideas about BIM mentioned in the interviews are analyzed and compared in this section. In Figure 6.6 are the comments on inventory model content and uses from all interviews mapped interview group specifically. In Figure 6.7 are the general comments on modeling and the creation of inventory models from all interviews mapped interview group specifically. Topics which are disagreed upon are marked red and comments on where the information should exist are marked in blue. The number after a comment shows how many interviewees had the same comment. The topics are marked with a number (1-14).

All interview groups agree that an inventory model should contain critical and bearing structures (1). Shaft dimensions are important to know for MEP-design. Light structures could be modeled if the model is used for calculating the demolition contract and ducts could be modeled if they are known. More detailed information about the structures such as structure age or load bearing capacity could also be added as element properties. Space reservations for MEP-systems would also be good to show in the model in e.g. lowered ceilings or shafts.

Interviewees disagree on what the modeling of structures should be based on due to the unknown accuracy of existing documents (2). Many agree that it is beneficial to create an inventory model from old drawings because it is cost efficient and structural designs are rather accurate. Many also agree that verification measurements should be done to improve the accuracy of the model. This all depends on the existence of old drawings and the knowledge about their accuracy. A counter point is that the content of the structures

	Structure	Spaces
Project Managers	[1]critical structures, [2]structural designs usually rather accurate, [2]structure content often not as designed, [2]model based on old drawings, [3]model used for early energy simulations	[4]no survey results but link to report, [5]not building protection, areas affected by devices
Construction Consultants	[1]shaft dimensions (2), [1]ducts in bearing structures if known, [1]building frame, [1]light structures if spared or if used for calculating demolish contract, [2]created from old drawings (2), [2]verification measurements needed(2), [2]no opened structures, [2]depending on existence of old drawings, [2]beams impossible to measure without opening structures	[4]space specific information generally enough, [4]not surveys in 3D while 2D enough, [4]moisture damages, [4]indoor air problems, [4]harmful materials, [4]link to survey reports, [4]problems during previous projects, [4]not problematic areas or renovation needs, [4]done renovations (2), [5]historical boundary conditions, link to space management system, beneficial to have all information in models, not cost effective to enter all information,
Architects	[1]bearing structures, [1]holes in structures, [1]shaft dimensions, [1]model of bearing structures good for all designers, MEP space reservations, structure age	[4]harmful materials, [5]building history, [5]protected parts, [5]link to building history report, [5]link to pictures of spaces, [6]architectural model beneficial if in the right format, [6]not architectural model while spaces usually change, [6]space model useful in IFC-format
Workplace & Facility Solutions	[1]location of parts (2), [1]Structural model useful also in smaller renovation	[4]condition & cost info, [7]not visualization model for marketing, [7]model for visualization of spaces for client (2), used for area & capacity & cost calculations, quality level assessment, linking of information for maintenance (2)
BIM-Experts	[1]architectural model too specific but light structural model useful for MEP-design, [2]cheapest and easiest created from drawing (3), verifying measurements needed (2), [3]existing frame model useful for making architectural space model used in the energy simulation in the conceptual design phase, [3]an existing model would make it easier to conduct early energy simulations	[3]an old space model would not be useful for energy simulations while the spaces would have the wrong properties, [4]3D model is not significantly more expensive to make than a 2D plan if the same space heights can be used at each floor, [4]in 3D model common problems on different floors easily noticed, [6]architectural inventory model-format to be chosen by project architect, only links to reports makes the information hard to find and update & read, possible to link information to an IFC-model, minimum information requirements in the model as space properties, not all information in the model but linked

Figure 6.6: Comments from all interviews on BIM possibilities for managing initial information divided into structural and space properties.

is often not as designed. This makes it impossible to know for sure what the content is unless structures are opened. Without opening structures the knowledge about the content can only be assumed or guessed. It is also pointed out that beams are impossible to measure without opening structures while verification measurements can not be performed otherwise. This takes us to the accuracy of the model and how elements should be marked (9) which is shown in Figure 6.7. Guesses should be marked in the model as guesses to provided knowledge about what is known and what is not known. When creating an inventory model the quality control and the documentation of the modeling conditions are of great importance. With the level of accuracy marked and shown in the model the responsibility of the model can be clearly divided between the different stakeholders.

Interviews from several groups mention that models could be used for energy simulations (3). It is pointed out that an existing frame model would be useful for making a new architectural space model which could be used for energy simulations in the conceptual design phase. An old space model would on the contrary not be useful for energy simulations because the spaces would have the wrong properties.

The main disagreement is about managing survey results with a model (4). Some argue that the model should not include survey results but only a link to the report. Others argue that central findings and major information about the survey should be entered as properties of the spaces where the surveys have been made. It is also concluded that it is beneficial to have all information in models but that it would not be cost-effective to enter all information. Space specific information was said to usually be specific enough and in an expert interview it was stated that it is possible to link information to the spaces in an IFC-model.

The information that should be managed with models is findings of harmful materials, moisture damages, problems during previous projects, indoor air problems, and the building condition. One interviewee argued that problematic areas or renovation needs should not be entered into the model. The reason for this is that these problems should be fixed and then only the realized changes should be entered into the model. Renovations which have been done could thus be marked in the spaces but not renovations that should be done. Areas affected by devices could also be shown in the model.

In the BIM-expert interviews it is pointed out that if the model only contains links to reports the information is hard to find, read, and update. Therefore should minimum information requirements be set for the model space properties. It is also concluded that not all information should be in the model but rather linked. Important to remember here is that even though the information is linked the main information should be machine readable.

In one interview it is said that surveys should not be shown in 3D-models while 2D-plans are specific enough. In a expert interview it is concluded that a 3D-model is not significantly more expensive to make than a 2D-plan if the same space heights can be used at each floor. The benefit of using a 3D-model is that common problems on multiple floors would be easily noticed.

Disagreements also arise about managing building protection with models (5). Some say that protected parts and other boundary conditions should be marked in the model while others say that building protection should not be shown in the model because it often affects the whole building and not specific spaces. If space specific boundary conditions and historical information exist these could be entered into the model space specifically. When a building history report is done it could also be linked to the spaces or to the building as well as historical pictures of spaces.

If possible the spaces should include links to space management and maintenance systems. In the expert interviews it was stated that the current space management and maintenance systems at Senate Properties do not yet support IFC-models and thus this is not currently an option.

The question about architectural inventory models (6) also cause disagreements. In an architect interview it is said that an architectural model would be beneficial if provided in the right format. An expert agrees that if an architectural inventory model is created it should be in a format chosen by the project architect. On the other hand it is pointed out that it would not be useful if an architectural inventory model would be provided because spaces usually change. A general space model would still be useful if it would be provided in the IFC-format.

While a model could be used for visualization of the spaces for a client (7) it was stated that it would not be effective to create an inventory model for marketing visualization of the building. For creating a few rendered pictures of a few chosen spaces it would not be necessary to have a whole technically detailed model as a basis.

It is commonly stated among the interviewees that models should not be created in all cases because it depends on what the model is going to be used for (8), seen in Figure 6.7. The intended model use sets the boundaries for the model content, the level of detail, and the accuracy of the model.

General thoughts on models (10) are that the information should be easily accessible and machine readable and the models have to be up-to-date and in an open file-format. The IFC-format is useful for transferring models including only geometry and main object properties while more detailed models should be exchanged in its native format if possible. The model could also be used as a checklist for initial information.

The model should be seen as an asset which adds value to the building.

	General comments	**Creation of model**
Project Managers	[8]case specific model benefit evaluation, [9]guesses marked, [10]information easily accessible, [9]model as checklist for initial information (2)	[11]not profitable before investment decision, [11]model useful in conceptual design if accuracy guaranteed, [12]difficult to make measurements if building in use
Construction Consultants	[8]little model knowledge in the industry, [8]case specific model benefit evaluation, [8]intended model use sets boundaries for model content (2), [10]models to be up-to-date, [11]inventory model highly beneficial	[11]before the start of the project for a quick start and clear division of responsibilities, [11]as early as possible
Architects		[11]before the design phase starts if model accurate(2), [11]not before the beginning of the design phase
Workplace & Facility Solutions	[11]space model beneficial in the Workplace and Facility Solutions process	
BIM-Experts	[8]case specific model need evaluation (2), [8]content and level of detail and accuracy depends on planned use (2), model to be seen as an asset, [10]information in an open file-format, [10]information machine readable (2), [10]use IFC to transfer model including geometry and main properties, [13]version update every 3 years (2), [13]native model updated and a new IFC-model exported from the native model (2), [13]accuracy and quality control of the updates checked through quantity take-offs from the old and the new model or through a comparison between the old and the new IFC model, [13]does not matter who updates as long as the requirements are clearly stated in the contract	[9]level of accuracy documented and marked in the model for a clear division of responsibility, [9]quality control and documentation of the modeling conditions, [9]knowledge about what is known and what is not known, [11]not requirement models in 3D, [11]before the design phase for a quicker start, [12]measurements when the building is in use, [14]if an old model exists is the process of making an inventory model to update and check the old model

Figure 6.7: General comments on modeling and creation of inventory models from all interviews.

The maintenance of the model must therefore be seen as a natural part of the facilities management.

It is commonly stated that an inventory model is highly beneficial in renovation projects. A major disagreement concern the time to create the model (11). It is said that it is not profitable to create a detailed inventory model before investment decision while the need for a model is still unknown. Another reason why a model should not be created before the beginning of the design phase is said to be that the designers should decide upon the model requirements together before a model is created. On the contrary should the model requirements be provided by the facility owner and not by the designers. A model was seen by project managers as useful in conceptual design if accuracy guaranteed. A space model was also seen to be beneficial in the Workplace and Facility Solutions process. Both BIM-experts and construction consultants said that the inventory model should be created as early as possible and before the start of the project for a quick start and clear division of responsibilities between the designers and the building owner. Architects also agreed that the model should be created before the design phase starts if the accuracy of the model could be guaranteed. Even though initial information should be managed with models the project requirements should not be managed with a 3D-model in the early phases of a renovation project because it would only make the work for the architect more complicated.

One argument for not creating a model earlier is that it would be difficult to make measurements if the building is in use (12). In an expert interview it was on the contrary stated that it is not a problem to make measurements when the building is in use. The problem is only that structures can not be opened.

6.2.3 Comparison of static information needs and BIM possibilities

In Figure 6.8 the static information needs and the perceived possible BIM content are compared. We see that most of the topics are common. In Figure 6.8 the information is grouped in the same way as in the information needs tables.

Most of the information is common but there are a few differences. Even though future renovations and surveys are to be known before the renovation this information is not perceived to be good to have in a model. One reason for this is that modifications should be done before the changes are made in the model. Another reason could be that modeling renovation needs could make the information static and thus provide a psychological barrier to make the needed changes. Information about problems during previous renovations can be seen as part of a well documented renovation. That is also the information about what has been done and not done as well as the reason for the renovation which is needed static information.

	Static information	**BIM content**
Structural properties 1 Dimensions 2Content 3 Other	[1]story height, [1]building envelope, [1]bearing structures, [1]structure boundary conditions, [1]structural elements in spaces, [1]shaft dimensions, [1]free space for systems, [1]holes in structures, [2]materials and harmful materials, [2]structure content, [3]structure strength	[1]critical and bearing structures, [1]shaft dimensions (2), [1]light structures if spared or if used for calculating demolish contract, [1]MEP space reservations, [1]ducts in bearing structures if known, [2]harmful materials, [3]structure age
Space properties 1 Areas 2 Use 3 Protection 4 Condition 5 Renovation 6 Survey	[1]gross and leased area, [2]building history, [2]current and previous use, [2]space flexibility, [3]museum boundary conditions, [3]protected parts, [4]moisture problems, [4]date and scope of occurred leakage, [4]prolematic areas, [4]designed air quality and sound level, [4]current quality and safety level [5]renovations and [6]surveys date, actions / findings, reasons, done and not done, future ones	[1]areas affected by devices, [2]building history, [2]link to building history report and pictures of spaces, [3]historical boundary conditions, [3]protected parts, [4]moisture damages, [4]harmful materials, [4]indoor air problems, [4]quality level [5]renovations and [6]surveys done, problems during previous projects, not needs, link to report
MEP-systems 1 Use 2 Condition	[1]use of each cable and pipe, [2]life length of MEP-systems	

Figure 6.8: Comparison of mentioned static information needs and BIM possibilities collected from all interviews.

A remarkable difference is that MEP-systems are not mentioned as important to have in the inventory models even though information about them is needed. A reason for this is that creating a model of MEP-systems requires a lot of effort and the usefulness of the model is unclear if it is not known if the systems are to be spared or completely removed. It is therefore better to wait for the start of the project to evaluate if the MEP-systems are to be modeled or not.

6.2.4 Secondary data from literature

In the ELVYKOR-project were a few remarks made on inventory models. These comments can be seen in Figure 6.9.

Place of Design	Observation	Recommendations
Corner points and dimensions of elevator shafts	Elevator shaft are useful as measurement points in cubic tests while they continue in an easily measurable line throughout the building. In addition to this is the free space of the shaft important information for renovations of the elevator.	Uncertain shafts and measurement points can be marked with space objects in which information about the uncertainty can be stored.
Location of beams in the ceiling	In old in-situ concrete structures all beams are not shown in the architectural designs. The dimensions of the beams shown in the structural designs are to be checked at the site if important MEP-system routes are planned close to the structures.	The structural planner models an own structural initial model which is compared to the initial model made by the architect.
Dimensions and skewness of shafts for MEP systems	Central information at the latest in the design development phase especially for the shafts which seems to be narrow in earlier design. Even though the dimensions of the shaft may be constant from floor to floor might the skewness of the shaft add significant extra costs due to extra turns for the electrical equipment or HVAC-ducts.	The accuracy of the dimensions can be shown through the attributes of the objects in the initial model.
Inner dimensions of existing technical spaces	The dimensions have to be known exactly so that they can be taken into account designing system and maintenance routes.	Maintenance routes are modeled as reservations as own objects.

Figure 6.9: Information needs found in the ELVYKOR-project (translated from Valtonen 2013 p. 6).

If we compare these findings to the findings in the ELVYKOR-project we see that all four topics have been mentioned in the interviews as well. For locating the beams in the ceiling opening structures is a prerequisite. As said in the ELVYKOR-report as well as in one interview this is only essential if MEP-systems are designed close to these objects. Thus, in an inventory model the exact location of beams can be assumed and the accuracy level marked and then later on checked by opening structures for getting the exact location of an object. The other topics also concern the frame dimensions and have an effect on the design of MEP-systems.

6.2.5 Conclusion on information in an inventory model

In Figure 6.10 are the useful minimum information requirements of inventory models shown based on the interviews. While the information can be clearly divided between structural and space properties two models have been defined based on these properties. The information is thus divided here into the following two model types: building frame model and space model. The information in the table is further divided between model content on the left and comments on the model on the right. Finally there are general comments which affect both types of models. The information is grouped into the same groups as in Figure 6.8.

The gross and leased areas have been removed from the space model. The reason for this is that because a building usually inhabits multiple clients, the leasing area might be difficult to model for each client separately. If a space model is made up of only spaces the gross area would also be hard to model accurately. The building frame model would contain the building envelope and bearing structures, and thus could the gross area be calculated from this model instead.

6.3 Validation workshop with BIM experts

A workshop was conducted to validate the findings. The aim was to hear experts' comments on the findings and hear alternative solutions to the found information management problems. The findings were presented for each research question and the following topics were discussed:

- validation of the useful minimum information,
- value creation through the use of models,
- choice of models and alternative models,
- model definitions,
- making of inventory models, and
- model maintenance.

	Content of inventory models	Comments
Building frame model 1 Dimensions 2 Content 3 Other	[1]gross area, [1]critical and bearing structures, [1]building envelope, [1]story height, [1]structure boundary conditions, [1]structural elements in spaces, [1]shaft dimensions, [1]free space for systems, [1]known holes in structures, [2]known materials and harmful materials, [2]structure content, [3]structure age, [3]structure strength	- model used for creating an architectural space model for early energy simulations - used for area and capacity calculations - exchanged in IFC-format - measurements when building in use - created from old drawings if old drawings exist - verification measurements - initially no opening of structures
Space model 1 Areas 2 Use 3 Protection 4 Condition 5 Renovation 6 Survey	[1]areas affected by devices, [2]building history, [2]current and previous use, [2]space flexibility, [3]museum boundary conditions, [3]protected parts, [4]moisture damages, [4]date and scope of occurred leakage, [4]designed air quality and sound level, [4]problematic or unknown areas, [4]harmful materials, [4]indoor air problems, [4]current quality and safety level [5]renovations and [6]surveys date, actions / findings, reasons, done and not done, problems during previous projects	- space specific information - space model without architectural details - not visualization for marketing - potentially same story heights - exchanged in IFC-format - minimum information requirements in the model as space properties - detailed information linked - created from old drawings if old drawings exist
General comments	- case specific model benefit evaluation - intended model use sets boundaries for model content - information easily accessible, machine readable, in an open file-format - models to be up-to-date - models created before the Workplace and Facility Solutions process - level of accuracy documented and marked in the model for a clear division of responsibility - quality control and documentation of the modeling conditions	

Figure 6.10: Useful minimum content of an inventory model based on the interviews.

It was commented that the third research question should actually be the first one. The reason to use the model and the benefits of it should be defined before the information needed for it can be collected. It was concluded that the information requirements for a renovation project depends on what the information is going to be used for and what is going to be done in the project. There are also different information requirements in different phases. The list of initial information shown in Figure 7.1 in chapter 7.1 is a good checklist even though each topic should be more specific. The list is at a highly generic level. The list probably includes information which is not always needed. Therefore every item on the list should be evaluated to find the absolute useful minimum. It can be done by asking interviewees for what purpose the information is needed. A generic useful minimum can probably not be found but useful minimum information requirements for renovation projects at Senate Properties would be possible to find.

Information about the parts of the building which are not known was emphasized by the participants as highly important. Information about what is not known has to be documented so that additional surveys can be made.

The separation of the building frame model and the space model was seen as an interesting alternative. Usually the spaces and the structures are in the same model. The MEP-specialist taking part in the workshop said that for MEP-design a model only including spaces could be highly beneficial.

It is better to use already defined model names if possible. In the COBIM part 1 a "spatial model" is defined as including spaces and the structure and would thus be a combination of these two models. Direct names for the two models presented are not found in the COBIM series.

The linking of information to the space model was seen as a possibility. In the space model the gross space and the floor space should also be modeled. Information regarding the whole building or a specific floor could in this way be linked to the right spaces.

Models should be created for one phase at a time. If the model can be used in a later phase it could be used then as well but the model should not be created for a later phase nor just in case. The model should be created by the designer who is going to use it and not for future designers. For a model to be useful it will have to be created using the same software as the designer is using. Thus, an inventory model can be created when the designer who is going to use it has joined the project.

Inventory models could be created in several phases. The first could be in the beginning of the Workplace and Facility Solutions process. The second phase is in the conceptual design phase and the third phase is in the design phase.

The need for a model has to be evaluated case specifically. A model which would always be useful can not be defined. There are too different needs for models in different projects and different phases of the projects.

A model can not be updated in the IFC-format while the format is meant for analyses and model comparison. A model has thus always to be updated in its native format and then exported as an IFC-model.

The maintenance of models was found to be too big a topic for being discussed in the workshop. The topic should be researched and processes for maintaining models should be created.

Chapter 7

Discussion

In this chapter the analysis results are discussed and alternatives evaluated. Recommendations for Senate Properties are given and topics for further research are proposed.

7.1 The useful minimum initial information

The initial information requirements for a renovation project are listed in Figure 7.1. These are all information topics that are always needed to be checked prior to a renovation project.

The information is divided into six groups: structural properties, space properties, site properties, MEP-systems, renovations and surveys, and accuracy of documents. As can be seen in Figure 7.1, the structural properties can be grouped into four main topics: (1) structural dimensions, (2) structure content, (3) structure condition, and (4) other. The dimensions are needed for knowing the boundary conditions of the spaces. They are further needed for the MEP-design where both the story height and the shaft size are relevant. Also existing spaces for MEP-systems including existing holes in the structures are needed to be known for a renovation project. The load bearing capacity of the structures is important information for planning the use of spaces. The strength of structures for security reasons are only needed for special buildings such as buildings used by the police.

The content of the structures are to be surveyed. Of interest are the materials used for both bearing and non-bearing parts such as insulation. Surveys are also needed for finding harmful materials such as asbestos and cinder stone. Also the condition of the structures are to be surveyed. This is to be done while water leakages or other accidents may have harmed the structures and some materials have become old.

	General initial information needs
Structural properties 1 Dimensions 2 Content 3 Condition 4 Other	[1]story height, [1]bearing structures, [1]building envelope, [1]structure boundary conditions, [1]structural elements in spaces, [1]shaft size, [1]free space for systems, [1]holes in structures [2]materials, [2]harmful materials, [2]structure content [3]general building condition, [3]structure condition [4]strength of structures
Space properties 1 Areas 2 Use 3 Protection 4 Condition 5 User feedback	[1]gross and leased area [2]utilization rate, [2]building history and age, [2]current and previous use, [2]space flexibility [3]museum boundary conditions, [3]protected parts [4]energy use history, [4]heat leakage, [4]moisture problems, [4]date and scope of occurred leakage, [4]indoor climate, [4]air quality, [4]draft, [4]radon concentration, [4]smell problems, [4]sound level, [4]problematic and unknown areas [5]workplace satisfaction, [5]current quality and safety level
Site properties	soil condition, location of municipal networks
MEP systems 1 Use 2 Condition	[1]use of each cable and pipe [2]condition, [2]life length of MEP-systems
Renovations & Surveys	date, actions / findings, done and not done, reason, future renovations and surveys
Accuracy of documents	accuracy of documents

Figure 7.1: Initial information needs in a renovation project.

The space properties can be organized into five groups: (1) areas, (2) use, (3) building protection, (4) condition, and (5) user feedback. The gross area is needed to set the project scope, the budget, and the schedule for the project. The leased area is needed for evaluating the costs for each client and thus the total acceptable cost of the project because most buildings are not single tenant buildings. The building use history is needed because it can show the technical boundary conditions. These can be the ventilation capacity restricting the maximum amount of people or the structural load bearing capacity which can restrict the placing of archives on the floors. The space flexibility can also be seen from the building history. It sets how much the client can develop their operations without renovations. The utilization rate is needed because it can show the need for development of the building if the rate is lower than required.

Museum boundary conditions are to be evaluated and protected parts are to be known. The façades of many buildings are protected and it is important to clarify if the building is protected before the beginning of a renovation. It should also be clarified if any internal parts are protected as well.

The condition of the spaces and the indoor climate are to be known similarly to the structural conditions. This includes the air quality, smell problems, sound level, and pollutants such as radon. Moisture damages are to be known because they might have damaged the structures or might be a reason for smell problems. The energy use history can show energy leakages which has to be taken into account in the renovation and help target actions. Also potential problematic areas are to be known so that additional condition surveys can be made. The clients feedback on the spaces which can involve the indoor climate and general workplace satisfaction is to be known. It also involves the current quality and safety level of the spaces. The quality level can for example involve the indoor climate. Knowledge about the safety level is not necessary for all users but it might be required by some users.

The site properties includes the condition of the soil and the location of municipal networks such as sewers and water pipelines. The soil condition is important to examine before the start of the project. Bad soil conditions can lead to major extra costs if not known.

The information needed about MEP-systems can be divided into two groups: (1) system use and (2) system condition. The use of each cable must be known so that cables not used can be removed and cables in use can be replaced when needed. If unnecessary cables are left it adds to the amount of burnable materials which affects the overall building safety. The condition includes the general system condition, specific information about devices, and information about the lifetime of the systems. Based on this information it can be decided which parts, if any, are to be kept and which are to be replaced. Only in the case of not replacing all MEP-systems detailed information about the systems are needed.

Renovations and surveys are combined into one group because the information needed about each of them is similar. The date of conducted renovations and surveys are to be known as well as what has been done and not done. Also the reasons are to be known, e.g. if a wall has been built for structural reasons or for dividing spaces. Also planned future renovations and surveys are to be known. Finally knowledge about the accuracy of documents is to be known. It is a topic covering all other groups. If the accuracy of existing documents can not be guaranteed the validity of all documents is questionable.

7.2 Models for managing initial information

For managing the initial information in a renovation project two inventory models should be created. The first inventory model is a building frame model including structural information. This inventory model is at the "must have"-level of the useful minimum principle. The other model is a space model for managing building information. The space model is at the useful minimum "should have"-level. Alternative extra models are also briefly discussed in this section. The alternative models are at the "nice to have"-level of useful minimum information requirements in a model.

The building frame model and the space model could also be created as one. This would be a "spatial model" as defined in the COBIM part 1.

A building frame model and a space model would meet many of the information needs for the Investment Management and the Workplace and Facility Solutions process described in chapter 3.1. In the process of creating the models the existing data would be checked and updated. The benefits of up-to-date data was concluded in chapter 3.1.

7.2.1 Building frame model

A building frame model should be created to manage the information about structural properties. The building frame model corresponds to the Preliminary Building Element BIM for the structural designer described in COBIM part 1 Appendix 1. The model should contain the dimensions of the bearing and critical structures of the building. This means the locations of beams, columns, bearing wall, slabs, and potentially also the building envelope. Figure 7.2 shows a snapshot from a building frame model without the building envelope. Exact knowledge about these structural properties enables preliminary MEP-design and gives a good picture of the space flexibility. Especially the shaft dimensions have to be accurate. Further, the object type and structure should be defined as precisely as possible. Structural properties such as load bearing capacity should be inserted into the object properties when known.

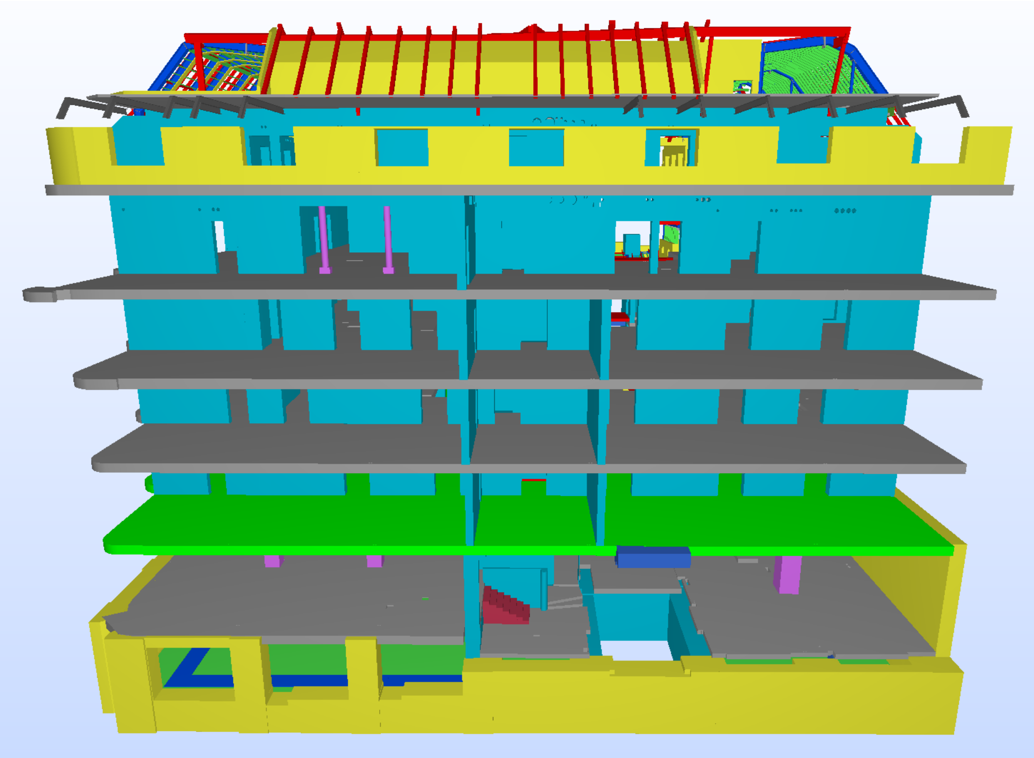


Figure 7.2: Snapshot from a building frame model (Perttu Valtonen / Sweco PM Oy).

Additional information which is needed for renovation projects could be added to the model. The existence of encapsulated harmful materials and object content can be inserted into the object properties. Properties of the elements such as structure age and element protection can also be added. The need for this has to be evaluated case specifically. Space reservations for MEP-systems could also be inserted into the model.

The building frame model should be created in the conceptual design phase by the structural designer. If the structural designer has not been attached to the project by then should the model be created as soon as the designer is chosen. The building frame model can be created from old drawings. By making verification measurements of chosen points in the building the accuracy of the model can be guaranteed. These points can be the location of columns e.g. at the basement floor. Columns can then be assumed to continue on top of each other. This assumption can be made to reduce the effort needed to create the model. In the first stage of creating a frame model no structures should be opened. This approach will enable taking measurements and modeling when the building is in use. On the other hand this will make it impossible to measure beams. This means that the locations and dimensions of beams can not be verified until in a later phase. In the model it is therefore important to show which parts have been measured and for which parts the locations have been assumed. If this is done appropriately, additional measurements can be taken at a later stage if needed for the parts which have not been measured. The accurate location of objects are needed for example if MEP-systems are designed close to the object. If it is found that the existing drawings are inaccurate, the model can be created from a point cloud based on a laser scan of the building. This has to be evaluated case specifically.

The accuracy of the building frame model should be improved when more information is at hand. The level of detail should not exceed the additional information requirements listed above. The model should in this way only include the useful minimum information requirements. This model should be used as a basis for inventory models with a higher level of detail created later on in the process.

A building frame model would be useful as a source for:

- accurate gross and net areas and story height data of the building,
- information about the structural boundary conditions and space flexibility,
- geometrical and load constraints for space planning, and
- visualization of existing information about the building and unknown areas.

The model would also work as a reference for:

- fittings of MEP-systems,
- design in all disciplines in a renovation project,
- visualization models in the maintenance phase, and
- comparing buildings corresponding to the clients needs.

The model would be useful for providing information about space flexibility and structural boundary conditions. The story height or structural elements in spaces might limit the use of the building. The earlier this information is acknowledged the easier it is to find alternative solutions.

If a frame model would exist already before the conceptual design phase it could be used for creating the architectural space model which is used for energy simulations. This would enable earlier energy simulations which are needed for the energy efficiency to have a bigger impact on the design. A frame model would also enable earlier fittings of MEP-systems. In the design phase the model would be useful for all design disciplines. All designers need information about the building structure.

In the process of creating the building frame model the existing building documents are checked. This gives knowledge about the existence and accuracy of the documents. This is one of the initial information requirements concluded in chapter 7.1.

7.2.2 Space model

A space model is here defined as a model only including spaces. It does not include building elements or objects within spaces. The space model can be compared to a 3D requirement model but including the existing spaces. The model is used for visualization, localization, and management of building information. The information is inserted into the space properties or linked to the spaces. The model need not contain exact dimensions of the building because it should be used only for organizing and managing information. The model could be created from old drawings and without the need for exact dimensions are no verification measurements needed. The story height could also potentially be the same on all floors in the model making the modeling process easier. The model should include only spaces without details and therefore not be used for marketing visualization. Figure 7.3 shows a snapshot from a space model.

The space model should be created in the beginning of the need evaluation phase by the architect.The model could be created with any program chosen by the architect and information should be linked to the exported IFC-model. The most important information should be stored in the model as space properties for it to be easily accessible and machine readable. The linked information could be in the form of reports and drawings. Also the linked information should rather be machine readable to enable data mining. The space model content is summarized in Figure 6.10.

The model should contain information about the areas affected by major devices. In this way the effect of taking one device out of commission could

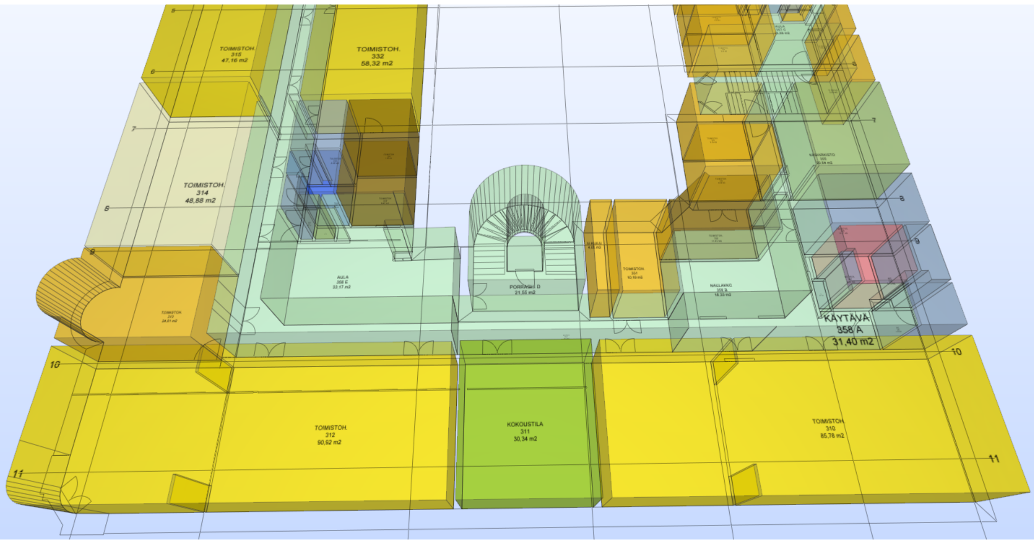


Figure 7.3: Snapshot from a space model (Perttu Valtonen / Sweco PM Oy).

be visualized. The use of the building and the space classification should be entered into the model. The spaces could be divided into offices, technical spaces, archives etc. When spaces are classified the model can be used to calculate the total area of specific room types. The gross area and the floor areas of the building should also be modeled as spaces. In this way information could also be attached to the whole building or to a specific floor. When a history report is made on the building the report could be linked to the model. This linking could be space specific or floor specific depending on what has been found in the report. Pictures of old structures or surfaces could for example be linked space specifically. Similarly boundary conditions by the National Board of Antiquities and possible protected spaces could be added to the model. If the safety level of the spaces are known this information could also be added to the model.

The space model should include information about the space condition and harmful materials. This could be information about water leakages, structural damages, and survey results. Thus, the model should include the condition of structures in or bordering the spaces. Also designed space properties could be inserted if known. The information that should be stored in the model about surveys is similar to the information about renovations. Important information which should be inserted in the model about these includes date, scope, reason, and problems occurred. Also comments on what has been left undone such as left enclosures of harmful materials should be marked. Reports and drawings included in these should be linked to the spaces. In the space properties should the most important space information be shown and more detailed information linked.

A space model would be useful for:

- managing building information,
- visualizing existing information about the building and needs for surveys,
- visualizing the current use of spaces in the building,
- anticipating potential threats and problematic areas, and
- ensuring that surveys are done prior to the investment decision.

The model would be useful for managing the existing information about the building. Through the process of collecting the data the existence of information would also be clarified. In this way the model could provide information about surveys that has to be made by visualizing which areas has been or not been surveyed. The model could also provide information about problematic areas such as possible moisture damages or existence of harmful materials. Through visualization of the current use of spaces could the architect easier get started with the design by getting a good overview of the building. The information would be more easily manageable and the need for further information gathering would be clear.

The main point of the model is to visualize and manage the existing information about the building. Areas which have not been surveyed or spaces including problematic areas can be shown upon request. Also the leased areas should be shown in the model if possible.

7.2.3 Alternatives

The need for a model has to be evaluated case specifically. The intended model use sets boundaries for the model content. Thus also other models could be useful. The following models can be created if needed.

Alternative 1: Modeling of light structures. This model would also includes the materials used at the structure surface. When measurements are taken it is important to document if it is the bearing structure or the actual wall surface that has been measured. This model could be used for better visualization of the spaces. The file-format is to be chosen by the project architect to avoid the need for remodeling. If a model is created at this level and a major renovation is done including partial demolition the demolition contract should be calculated based on the model. Otherwise the model would not be efficiently used. Thus, this model could be created in the beginning of the renovation project when the use for a model is known and the architect has been chosen.

Alternative 2: Modeling of MEP-systems. This would be useful if the MEP-systems are not removed in a coming renovation. The model could be created based on existing MEP-design documents. For the model to be accurate verification measurements should be made. This requires opening of structures, especially the ceilings, which can hardly be done when the building is in use. Thus, this model should only be created when it is clear that the MEP-systems are not completely renewed and the building is not in use. A MEP-model could also be created for operations if the need for it is concluded. If this is done separately from renovations and structures are not opened, the model can only be as accurate as the existing drawings. A report on creating this kind of a model was written for Senate Properties in 2006 (Hyytinen 2006).

Alternative 3: Modeling of space details. Modeling details of spaces such as windows, doors, and terminal devices can be done as well. This high level of detail model would be useful when evaluating the need for a renovation, for getting to know the building, for building maintenance, and for smaller renovations. It would also be useful for marketing visualization. It would on the other hand not be useful in the design phase of a major renovation project because most of the details would be changed. If this kind of model would exist in the form of an as-built model and maintained during the building maintenance phase it could also be used as an inventory model. In most cases creating this kind of inventory model would not be worth the effort compared to the added value. The need for a high level of detail model has to be proven case specifically and the model should thus only be created when it is clear what is going to be done in the renovation.

Alternative 4: Linking information to current 2D-plans. If a space model is not created could the information instead be linked to spaces in 2D-plans. The need for a space model has to be evaluated case and phase specifically. What is lost by having 2D-plans instead of a 3D-model is the visualization of the building as a whole. By using plans each floor has to be examined separately and can not be viewed at once.

7.2.4 Use of the models in knotworking

The early existence of models would also be a good basis for knotworking in the initial phases of renovation projects. Knotworking is when a group of people with knowledge about different disciplines come together to solve a common problem. This can be used in construction and renovation projects when designers of different disciplines work together to design difficult parts and to find the overall best solution for the project. It can be compared to the “Big room” idea. BIM is a tool to be used in knotworking.

Knotworking could be used for:

- managing objectives,
- understanding the project implementation,
- supporting the decision making process, and
- improving the quality and the efficiency of processes.

Knotworking enables close collaboration between experts of different disciplines. The target is to work together instead of only having meetings and then working separately. Also the understanding of the customer’s need is improved. (Kerosuo, Mäki, and Korpela 2013.)

7.3 Model creation

This section discusses the methods and phases of creating inventory models.

7.3.1 Phases

Figure 7.4 shows when inventory models should be created. There are three phases in the process of creating and developing inventory models as described below. The reason for creating models in phases is that the earlier information is provided the better. The problem is that information is needed before the accuracy of the information can be guaranteed. It is thus important to be able to cope with incomplete information and models not including all information that will be needed at a later stage. Models should therefore be marked in places which are inaccurate or where the information is incomplete so that the information can later on be updated.

The need for a model should be evaluated in every phase. If a need is not found a model should not be created in that phase. Models should not be created for the later phases because the usefulness of the model can not be defined beforehand. If the same designer is not in the next phase the created model might even be useless if the next designer does not use the same software. Thus, models should be created to fill the needs of the current phase and the current designers.

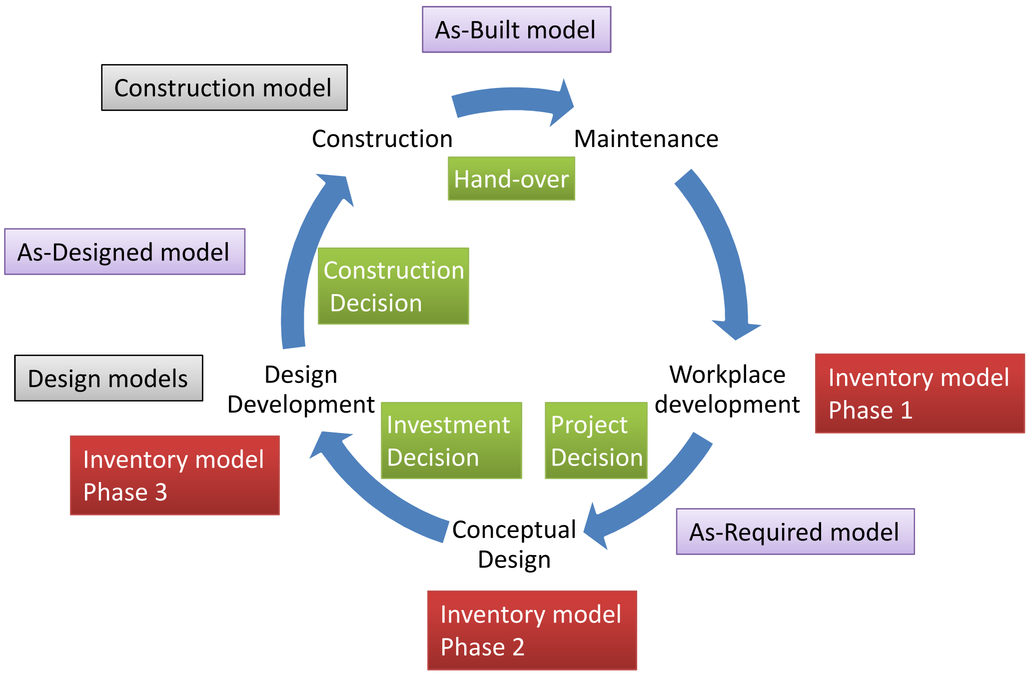


Figure 7.4: Phases when inventory models should be created.

The first phase of creating inventory models is in the beginning of the need evaluation phase. This is when the space model should be created based on existing drawings. In the interviews it was concluded that inventory models should be created before the design phase starts. It was also concluded that models could be useful in the Workplace and Facility Solutions process. The reasons for creating the model was concluded in chapter 7.2.2. The reasons for creating the model before instead of after the need evaluation phase depends on the use of the model in that phase. The main benefit is that the earlier information is available the easier it is to take action.

The second phase of inventory models is in the conceptual design phase. In this phase the building frame model should be created if it is concluded that there is a need for a model. The space model is complemented with the results of the surveys done in the need evaluation and conceptual design phase. This is important for having all information at the same place. If the model does not contain all relevant information it can not be relied upon and the benefits of the model are lost.

The third phase of creating inventory models is in the beginning of the design phase when the designers have been chosen. Based on the planned uses of the inventory model one of the alternative models described in chapter

7.2.3 can be created in this phase, if it is found beneficial for the project. If models are created the building frame model should be used as a reference. This should be done by the project designers who should chose the file-format for the inventory model. When the building is empty and structures can be opened additional measurements should be taken in places that are marked as inaccurate in the inventory model if seen as important. The accuracy of the initial building frame model is improved keeping in mind that it should only contain the useful minimum information. The space model is not updated at this phase if the spaces have changed. The relevant information which should be saved should instead be linked to the new space model.

7.3.2 Methods

The models should be created in such a way that everything modeled should be useful and that nothing should be remodeled. The model description document could be used as a documentation of the process of checking the existence of information. The document could in this way summarize which documents have been found and what information is not found e.g. drawings of some parts of the building. Alternatively, a separate information checklist could be written simultaneously which could contain this information. Also surveys that have to be made could be listed in the document. A building history report could be made simultaneously and linked to the space model.

In the model description document the level of accuracy and made assumptions should be well documented. It should be clear which parts are measured and which dimensions are taken directly from existing drawings. The level of accuracy of the model and the assumptions made should also be marked in the model. The modeling requirements should be provided by the building owner and the quality of the inventory model should be controlled. Quality control of the models and the documentation of the modeling conditions is highly important if the models are to be created at an early stage. If the quality and accuracy of the models can not be assured the existence of the models is not justified. By showing what information is accurate and what is not accurate in the model is the responsibility clearly divided between the stakeholders.

The accuracy could be marked in the model using levels with different colors. For example, green could mean that the objects location has been measured, yellow that the location has been taken from drawings, and red that the exact location has been assumed. The assumptions can be based on drawings of other parts of the building, knowledge about building of that type, or measurements of elements related to the marked object.

The verification measurements could be done using laser scanning but other methods are also possible. The required level of accuracy and the number of points to be measured has to be clearly defined in the contract. This clarifies the accuracy of the needed measurements and gives equal possibilities to the companies taking part in the tendering.

7.4 Model maintenance

It is highly important that models are kept up-to-date. If the information in the model can not be relied upon, the existence of the model is not justified. This section discusses the possibilities to maintain models.

Models should be stored in the IFC-format. It is important to use an open data format to avoid vendor locking. The information has to be easily accessible and machine readable.

7.4.1 Model update

The need for updating a model should be evaluated every three years (Jokela, Laine, and Hänninen 2012, p.17). The model should be update in its native format from which a new IFC-model should be exported. If no changes have been made to the building the model should still be updated to newer versions in periodical updates to avoid compatibility issues when the model is finally used. If smaller changes have been made to the building, such as smaller renovations, the model might not have been used in the project. These changes should be included in the model in this periodical update. When major renovation projects take place should the inventory models be used and updated.

The accuracy and the quality control of the updated models have to be checked. This can be done through a comparison of quantity take-offs from the old and the new native model. The quality can also be controlled through a comparison of the old and the new ICF-model.

The less content in a model the easier to assure that no information is lost in the update. Thus, the building frame model and the space model should not include more information than the useful minimum. This content is described in chapter 7.2.

The model maintenance can be outsourced to a firm having the necessary software. The requirements have to be clearly stated in the contract. This includes; content to be updated, frequency of updates, quality control, responsibilities, and copyrights.

The maintenance of models should be seen as a part of the building maintenance. Thus, the cost of the model updates should be included in the facility maintenance budget.

If an old model exists and has not been kept up-to-date, the process of making an inventory model is to update and check the old model.

7.5 Recommendations for Senate Properties

In this section the recommendations for Senate Properties are presented. The findings presented above are here applied to the processes at Senate Properties.

7.5.1 Initial information requirements

The useful minimum initial information requirements concluded in this thesis are to be acknowledged at Senate Properties. A framework should be created as a checklist for managing the information in renovation projects. In this way the results are to be implemented. The framework is to be developed and improved through the use of it in renovation projects.

7.5.2 Use of BIMs

A building frame model should be created in the conceptual design phase instead of the design phase. The need for a model should be evaluated case specifically.

Space models should be created to manage the building information. The need for a model should be evaluated case specifically. The content and the uses have to be clarified in the process. Also the leased areas should be visualized in the model when Optimaze enables support for IFC-models. Until then the client information, such as leasing areas and contracts, should be kept separately from this model. The data collected from surveys and renovations should be saved in Granlund Manager as it is done today. When the inventory models are updated should the needed information be inserted into the models from Granlund Manager. If it is concluded that there is no need for a space model in the Workplace and Facility Solutions phase the information can be managed in alternative ways using Optimaze and Granlund Manager. Information can be linked to 2D-plans as described in chapter 7.2.3. This is currently done partly because information about the client and their leasing contracts are linked to the spaces. Alternatively, the plans could be exported to Granlund Manager and the information linked to the 2D-plans in that system instead. These alternatives could be used before Optimaze and Granlund Manager supports IFC-models. The most important thing is that the information needs in each phase are evaluated and the existence of information is checked.

The models would provide more accurate information throughout the processes. They should thus be seen as a support tool for making good investment decisions.

7.5.3 Model creation

Requirements have to be set for inventory models. This includes how models should be ordered and what the models should include. The table listing model creation requirements which is as an appendix to COBIM part 2 should be developed to better suit the needs at Senate Properties.

The modeling requirements should at least include:

- level of detail
- amount of points to be measured
- exact content of models
- responsibilities
- quality control
- copyright of models

A template for the model description document should be created to fit the needs at Senate Properties. This could be used as a checklist for controlling the existence of documents. A checklist could also be created separately.

The responsibilities when creating a model have to be clarified in the contract. This includes who is responsible for the accuracy of the model if it is used in a future renovation project. This issue is solved by marking levels of accuracy in the model. Quality control is of great importance and has to be clearly defined in the contract as well.

The reason for creating a model before the project can be that uses for the model can be found in the maintenance phase. If a model is created already during the maintenance phase a cost structure should be developed. One alternative is that the first inventory models are created as a part of the building maintenance. In this case should the ordering of models be at the facility manager's responsibility. Another alternative is that the creation of the first inventory models are done as a special project where models are ordered for several buildings at a time. In this case could the responsibility of ordering the models be that of the project manager. The second alternative would be beneficial for the tendering process because it would be a larger number of models ordered at once. There are several possible solutions for the cost structure including:

1. the cost is seen as a part of the maintenance cost,
2. models for several buildings are created as a project which is financed as a whole separately from the buildings,
3. the costs for the model are covered by a loan from a future renovation.

These solutions and other possible solutions should be evaluated and a cost structure should be decided upon.

A BIM-template could also be created as a basis for modeling according to the existing concepts. This would simplify the modeling process for the architect. The template has to be created in the major BIM-softwares used by architects in Finland, i.e. ArchiCad and Autodesk Revit.

7.5.4 Model maintenance

The maintenance of models has to be researched. It has to be clarified what needs to be maintained and at what frequency. Further, it should be decided whether the models should be in a specific file-format or not.

The model should be seen as an asset which adds value to the building. The value comes from having accurate information for renovation projects and leasing which lowers the risk for clients and contractors and thus the required risk-premium. The maintenance of models should therefore be seen as a natural part of the building maintenance. Thus, the costs of the model maintenance should be included in the facility maintenance budget.

7.5.5 Information management

The findings in this thesis are applicable to information management in general as well as managing initial information. Knowledge about the accuracy of existing documents and general quality control is always important.

Information systems have to be user friendly if they are to be used. At Senate Properties the information is currently not saved according to standards and principles which is partly due to the complexity of the systems. The information management has to be managed and controlled. Documents are currently often either not up-to-date or not existing in some information systems. Projects have to be documented according to Senate Properties' principles if the information is to be managed. The information systems can not be used correctly if information is not provided and documents are not up-to-date. Thus, these are prerequisites for managing any building information.

7.5.6 Long term vision

In the long term the building information should be managed throughout the building life cycle without information loss between phases. This could be done through model based information systems with machine readable information. This would included total building life cycle information management with linking between systems. In the beginning of a renovation project all needed initial information would be easily taken from up-to-date maintenance models. This requires that models are used in facilities management.

7.6 A new business model

Model maintenance could become a possible new business model. According to COBIM part 12 owners should maintain their building model. Models should be maintained in their native formats requiring licenses for many BIM-software. For a facility owner managing many buildings it would be difficult to keep the models up to date. The facility owner could either create an in-house department providing this service for the individual buildings or the model maintenance could be outsourced. Currently there are not many companies in the Finnish markets providing this service. A company specializing in model maintenance could thus find a demand for this service on the market.

7.7 Limitations of research and methodology problems

The thesis is based on a sample of interviewees and projects. Therefore these findings may not be the absolute useful minimum, rather a first definition of the useful minimum initial information requirements for renovation projects. A bigger sample would enable a more precise definition of the useful minimum information requirements. The list shown in chapter 7.1 does not only include the useful minimum information as concluded in the workshop. Part of the information is not always needed, but it has to be checked prior to a renovation project. The list of information should be evaluated further e.g. through surveys or by asking interviewees why the information is important and if it is absolutely needed. The problem is that no one wants to go through with a construction project where only the perceived useful minimum information is available because it might not be enough. It is generally concluded that the more information the better. The results of this thesis should be critically evaluated and used as a basis for further research. After these results have been compared with many more cases and used as a checklist in other projects more precise useful minimum information requirements can be concluded.

Problems occur in research due to the chosen methodology. In this research semi-structured interviews were conducted with a limited amount of interviewees. Person biases are to be taken into account because people think differently and mention different things. It is commonly known that there are cultural barriers toward adopting new technology. Thus, interviewees might have given answers which would reduce the seen benefits of BIM. In the interviews the same questions were not asked of all interviewees because their tasks differ. Some questions were not asked in all interviews because some information was already collected. Questions were neither re-asked in the same way in all interviews and the lengths of the interviews differed. Therefore are the interviews not completely comparable. The total amount of interview material is still a valid basis for the research and biases are partly removed in the analysis.

The interviewees were asked what information is needed in the project and not in a specific phase. By asking phase specific questions the information could have been better compared between phases and space specific useful minimum information requirements could have been concluded. Similarly, the benefits of models in each phase could be elaborated.

Because the research was done for Senate Properties, which is a facility owner, interviews were a good research method. If the thesis would have been written for a construction consulting company the research could instead have been done by testing the possibilities in a real renovation project. This would have provided a more technical view on the topic.

In this research the information needs were first gathered and evaluated. Then the possibility to use BIMs for managing information was evaluated and the benefits of the models were discussed. The results of this approach are possible ways of using BIMs, without evaluating if BIMs are the best way to manage the information. The research could instead have started from the phase specific needs and the benefits of using BIMs, continued with studying BIM alternatives, and ended with the information requirements for the specific models. This approach would provide a reason for using BIMs instead of alternative solutions.

The research could have been divided into two research topics: (1) initial information needs and (2) benefits of using BIMs in the early phases of renovation projects. The first topic could have been researched in the same way as this research was conducted. The second topic could have been researched starting with benefits of BIMs and ended with information requirements. The second topic is more technical and could have been studied through practical cases or interviews with BIM experts.

7.8 Further research

Based on this research additional research can be conducted. The useful minimum information requirements of as-built models should be researched. In the long run an as-built model should be an as-maintained model which would be an up-to-date inventory model. The information needs of an inventory model is concluded in this thesis. Thus, future research should focus on what information is needed in facilities management. This includes who provides and is responsible for the information in the as-built model, and in what phase of the construction project the data should be collected. The useful minimum content of as-built models is also needed for model maintenance.

Model maintenance is only partly studied in this thesis. Further research is needed for creating processes for model maintenance.

Another research topic would be the linking of information between information management systems for facilities management. In this thesis it is concluded that IFC-models can not currently be used for managing information in the facilities management systems at Senate Properties. For having accurate and up-to-date information the information management systems need to be compatible and integrated.

The direct use of models in condition surveys should be researched. In this thesis it is concluded that survey results are to be entered into a space model and the report linked to the space. How the models can be beneficial in the surveys and how the findings can be better shown in the model are potential subtopics for future research.

Chapter 8

Conclusions

The aim of this thesis is to assess the useful minimum information required for utilizing building information models in the early stages of major building renovation projects. The main conclusion is that information has to exist, be up-to-date, be accurate, and the quality of the information has to be assured. For this to be possible the information management processes need to be managed and controlled. Five research questions presented in the beginning of the thesis are answered in chapter 7 and concluded here.

The first research question regards the information requirements in the early phases of renovation projects. It is concluded that the initial information requirements can be divided into the six groups; (1) structural properties, (2) space properties, (3) site properties, (4) MEP-systems, (5) renovations and surveys, and (6) accuracy of documents. For finding the useful minimum information requirements should the list presented in chapter 7.1 be further evaluated through interviews or questionnaires.

The other question is how this information can be managed with BIMs. It is found that there is a need for two inventory models. One building frame model should be created in the conceptual design phase to provide exact dimensions of the building structure. The frame model should be created by the structural designer. A space model could be created in the beginning of the need evaluation phase to manage building information which should be inserted into the space properties or linked to the spaces. If a space model is not created the information can be managed using 2D-plans even though this alternative would miss the benefits of seeing several floors at a time. The models should be created for one specific phase and if possible also be used in following phases. The most important thing is that the information needs in the phase are evaluated and the existence of information is checked.

Research question number three is how value is added to the organization through the use of these models. The following benefits are concluded: (1)

better control and management of existing building information, (2) more accurate and up-to-date information, (3) provide a quicker start to renovation projects, and (4) enable early energy simulations for a greater impact on design solutions.

The fourth question regards when and how inventory models should be created. The earlier decisions can be made the bigger impact they have on the outcome of the project and the cheaper they are to implement. Models are easier to understand than drawings which reduces misunderstandings in projects. Thus, models should be created and used as early as possible. This also means that models can not contain all information at an early stage. It is important to be able to cope with incomplete information which will be specified in a later stage.

When the needs for models have been clarified in the beginning of a renovation project models should be created. In the second and third phase new inventory models should be created to meet the needs in those phases. The need for a model should be evaluated in every phase. If a need is not found a model should not be created in that phase. Models should be created in such a way that nothing is modeled twice and nothing unnecessary is modeled. The most important thing when creating models is that assumptions and levels of accuracy are well documented in the model description document and marked in the model. In this way the responsibility of the information accuracy can be divided between the stakeholders.

The last research question is how building information models should be maintained. In the thesis it is concluded that the need for updating models should be evaluated every three years. The maintenance of models should be seen as a natural part of the building maintenance and the costs are to be included in the facility maintenance budget. The information to be maintained in the models is concluded in this thesis. If an as-built model exists, the information is to be updated depending on the uses for the model which are to be evaluated. This topic needs further research.

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Appendix A

List of interviewees

Alatalo, Kari. Development Manager, Senate Properties. Helsinki. Interview 29.11.2013

Fabritius, Kasper. Head of Workplace and Facility Solutions, Senate Properties. Helsinki. Interview 11.12.2013

Forsman, Sakari. Architect, Arkkitehtitoimisto Sarc Oy. Helsinki. Interview 22.11.2013

Gyllenberg, Toni. Consultant, Rapal Oy. Helsinki. Group interview 24.1.2014

Halmetoja, Esa. Development Manager, Senate Properties. Helsinki. Interview 18.12.2013

Hietanen, Jiri. BIM expert, Datacubist Oy . Helsinki. Interview 14.1.2014

Hirvonen, Petri. Senior Consultant, Rapal Oy. Helsinki. Group interview 24.1.2014

Ilomäki, Harri. Project manager, A-Insinöörit Rakennuttaminen Oy. Helsinki. Interview 5.11.2013

Järvinen, Tero. BIM Manager, Granlund Oy. Helsinki. Interview 22.1.2014

Ketola, Janne. Project manager, Sweco PM Oy. Helsinki. Interview 12.11.2013

Kuusisto, Jorma. Project manager, ISS Proko Oy. Helsinki. Group interview 5.11.2013

Laine, Joni-Marko. Product Manager, Senate Properties. Helsinki. Group interview 24.1.2014

Lukander, Minna. Architect, Arkkitehtuuri- ja muotoilutoimisto Talli Oy. Helsinki. Interview 3.12.2013

Malm, Teppo. Expert in Building Services Engineering, Senate Properties. Helsinki. Interview 1.11.2013

Niskakangas, Tomi. HTH specialist, Senate Properties. Helsinki. Group interview 24.1.2014

Nybonn, Sonja. Adviser, Workplace and Facility Solutions, Senate Properties. Helsinki. Interview 23.10.2013

Pesonen, Juha. Project manager, ISS Proko Oy. Helsinki. Group interview 5.11.2013

Rajala, Marko. CEO, Tietoa Finland Oy. Helsinki. Interview 13.11.2013

Ristolainen, Kari. Project manager, Parviainen Arkkitehdit Oy. Helsinki. Interview 11.11.2013

Ryynänen, Tiina. Senior Consultant, Rapal Oy. Helsinki. Group interview 24.1.2014

Saarinen, Aimo. Adviser, Workplace and Facility Solutions, Senate Properties. Helsinki. Interview 18.12.2013

Selänne, Sinikka. Chief Adviser, Senate Properties. Helsinki. Interview 18.12.2013

Toppinen, Asko. Construction project manager, Senate Properties. Helsinki. Interview 29.10.2013

Turunen, Pekka. Construction project manager, Senate Properties. Helsinki. Interview 1.11.2013

Valtonen, Perttu. BIM expert, Sweco PM Oy. Helsinki. Interview 15.1.2014

Ölander, Erkki. Architect, Arkkitehtitoimisto Sarc Oy. Helsinki. Interview 20.11.2013

Appendix B

Interview questions

Questions to project managers, construction consultants, and project architects

1. Which initial information about the building is needed in the beginning of a renovation project?
2. Were all the needed information available in this case?
3. Where did you get the information from?
4. Do you think BIM could be used to manage this information?
5. How do you think the project went as a whole?
6. Were there any surprises during the project?
7. Which problems occurred during the project?
8. Was there anything that should have been done in an earlier phase?
9. Was the information explicit enough?
10. How and by whom was BIM used in the project?
11. What were the benefits of BIM?
12. Where do you think the use of BIM was a waste of time, and why?
13. When should an inventory model be created?
14. What information should be in the inventory model?

Questions to the Workplace and facility solutions team

1. What information about the building is needed in the Workplace and Facility Solutions process?
2. Is the needed information usually available?
3. From where is the information taken?
4. Is the information explicit enough?
5. How do you thing BIM could be used to manage a part of this information?
6. Do you think BIM could be used to improve the client's experience?
7. What information about the building is important to the clients?

Questions to BIM-experts and information management-experts

1. When and how should inventory models be created?
2. What information should be in the inventory model?
3. Linking of information to models?
4. How should models be maintained?
5. Model formats and modeling responsibilities?

Appendix C

Validation workshop

List of persons attending the workshop:

- Jiri Hietanen (Datacubist Oy)
- Perttu Valtonen (Sweco PM Oy)
- Tero Järvinen (Granlund Oy)
- Marko Rajala (Tietoa Finland Oy)
- Auli Karjalainen (Senate Properties)
- Juho Malmi (Senate Properties)
- Kari Alatalo (Senate Properties)